# Interactions between cash and derivatives bond markets: some evidence for the euro area

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## Abstract

This paper provides a broad empirical examination of the interactions between cash and derivatives markets for government bonds in the core euro area countries (Germany, France and Italy) in the aftermath of the launch of the third stage of European monetary union (EMU). Since the launch of the euro, liquidity in derivatives markets has concentrated in a handful of capital market futures contracts, in particular those traded on Eurex. The tremendous level of activity in Eurex contracts has raised concerns about the risk of a shortage in the cheapest bond to deliver. The paper assesses cash market-, repo market- and futures market-based approaches to preventing such shortages, and finds that a combination of approaches is preferable.

The paper goes on to analyse how changes in liquidity and trading activity in government bond markets since the start of EMU have affected price formation. Based on the conceptual framework set out by the financial market microstructure and asset market equilibrium literature, econometric evidence on the determinants of yield spreads is presented. The results confirm that fluctuations in yield spreads across euro government bonds contain a significant transitory component, which could represent temporary deviations from fundamental values. This “mispricing” component increased at the time of the Russian and LTCM financial crises and peaked around the launch of the euro. Based on the size of the estimated mispricing component in bond yields, liquidity in euro government bond markets returned to pre-1998 levels during 2000. Moreover, liquidity conditions appeared to converge across the G5 countries, although UK and US bond markets maintained a positive liquidity differential with respect to euro area markets. Among euro area government securities markets, prices appear to be least distorted, and liquidity closest to that of the UK and US markets, in Italy's cash market, perhaps reflecting the advantages of an advanced trading infrastructure.

## 1. Introduction

This paper provides a broad empirical examination of the interactions between cash and derivatives markets for government bonds in the core euro area countries (Germany, France and Italy) in the aftermath of the launch of the third stage of European economic and monetary union (EMU). In our analysis we place special emphasis on the changes under way in the government bond market structure, integration and linkages and their implications for the relationship between prices, trading volume and liquidity in the main segments of the European fixed income securities markets.

Since the advent of the euro, market participants have been intensively discussing the effects and consequences of a more integrated money and bond market in Europe. While the precise role of EMU may be difficult to determine, the euro is widely recognised as perhaps the major factor that triggered the dramatic transformation of European capital markets.[2] By wiping out currency risk, the euro has eliminated an important source of segmentation in the supply of debt instruments. By speeding up the process of market integration, the single currency has increased the potential demand for national bonds and intensified competition among sovereign issuers, providing a strong incentive to reform

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[2] See Danthine et al (2000) for a broad assessment of the impact of the euro for the emergence of a pan-European capital market.

markets and pursue efficiency and transparency standards. Unprecedented issues in public debt management for the 12 independent sovereign states have been raised concerning whether, and to what extent, coordination and cooperation among them would be required to foster market integration. More recently, decreasing public debt and the prospect in Europe of further budget consolidation and, possibly, surpluses, as a result of the implementation of the Stability Pact, may have profound implications for the smooth functioning of European capital markets. In addition, the impact of more recent government measures, as triggered by the announcement of buyback plans by the US Treasury and the sales of UMTS mobile phone licences in the core countries of the EMU, has spurred relative value adjustment across the maturity range and issuers in the European bond markets.

As the fixed income markets change shape in Europe a process of adjustment is under way in the dynamic of price discovery about macroeconomic fundamentals owing to shifts in supply and liquidity. As a result, yield spreads are responding to a new ebb and flow of liquidity across markets. We aim at providing some assessment of the main factors underlying the recent trend of widening bond and swap spreads in the euro area. Some econometric evidence is brought to bear on the determinants of such recent developments, in order to identify the sources of changes in the factors driving the adjustment process. We intend to ground our econometric analysis in the conceptual framework provided by the recent literature on financial market microstructure and asset market equilibrium.

The paper is organised as follows. Section 1 attempts to provide an overview of changes and innovations in the European cash and derivatives markets for government bonds resulting from stronger competition between futures exchanges and products. One of the most interesting and heavily traded markets is the segment for 10-year government bonds and the related interest rate futures and swap contracts. Section 2 examines both the consequences of the transition to monetary union and the strategic innovations introduced by Eurex and MATIF on the 10-year Euro Bund futures contract and the 10-year Euro Notional futures contract respectively as the most important 10-year interest rate futures contracts traded in Europe. The data used for this part of the paper cover the period from mid-1998 to mid-2000. In Section 3 we provide a methodological assessment of the relevant concept of liquidity and related liquidity measures based on the dynamic decomposition of price effects into transitory (“mispricing”) and permanent (“fundamental value”) parts. In Section 4 we deal with the econometric application on the measurement of information efficiency and price behaviour of bonds, swaps and interest rate derivatives in the euro area. Finally, Section 5 concludes by summarising our main results.

## 2. Upheaval in the European cash and derivatives markets - an overview of developments since the transition to monetary union

Derivatives markets, being an integral part of the international financial markets, are subject to constant change. One of the most extraordinary changes regarding exchange-traded interest rate derivatives has been the worldwide increase in electronic trading, leading to an ongoing displacement of floor trading in interest rate futures. Furthermore, the growing corporate and agency bond markets have affected international interest rate derivatives markets, resulting either in more intensive trading in derivatives products or leading probably to shifts in the respective weight of OTC and exchange-traded interest rate derivatives. Finally, the transition to EMU has caused lasting changes, adjustments and problems for the European derivatives markets, which are presented in detail in the following sections.

Looking first at exchange-traded interest rate derivatives in the three main trading areas Asia, North America and Europe, the respective development of turnover shares for interest rate futures demonstrate that no major shift has occurred in trading activities among these areas.[3] The ongoing tendency towards electronic trading of interest rate derivatives has apparently caused major shifts within each trading area, particularly in Europe, but there is no evidence of major changes worldwide, despite remote membership of electronic exchange trading systems for interest rate derivatives. However, a clearer trend between the two main interest rate derivatives, swaps and futures, has

[3] See Annex 1.

become apparent during the past few years. While the global outstanding amounts of interest rate futures, primarily used for hedging cash positions in government bonds, remained stable during 1998 2000, the outstanding amounts of interest rate swaps expanded strongly during the same period.[4] A similar evolution, with slightly decreasing amounts of interest rate futures outstanding, is evident in the euro area.[5] As interest rate swaps and non-government bonds as a rule show stronger correlations in terms of their yield movements compared with those of interest rate futures and non-government bonds, the global growth of swap markets seems to be attributable to the worldwide increase in cash market activities in non-government bonds, leading to rising hedging requirements.

Following this more general overview of the evolution of interest rate derivatives markets, the focus will now turn to the European exchange-traded derivatives markets.

At the beginning of 1998, the respective percentage shares of the major European futures exchanges in capital market products already revealed a slight lead of Eurex over LIFFE, which up to 1997 was the largest European futures exchange.[6] However, MATIF and the Spanish futures exchange MEFF also accounted for sizeable percentages of the total contract volume in European capital market futures.

The situation changed fundamentally in mid-1998 and moved further in favour of Eurex, which accounted for nearly 4 out of every 5 futures contracts on fixed income underlyings traded prior to the start of stage three of EMU. This constantly rising trend in the trading share of capital market futures won by Eurex was broken by MATIF in December 1999, when Eurex's market share of the total trading volume in European capital market futures peaked at 95%. In the course of 2000, MATIF gained market share in contracts relating to European capital market products, rising to as much as 25%.

What is the reason for the marked increase in MATIF's market share?

Annex 5 shows the market shares of 10-year interest rate futures contracts held by each European futures exchange. It confirms that the revival in trading in capital market products at MATIF has been based almost exclusively on an increase in traded contracts in the 10-year Euro Notional futures contract which, in fact, reached a market share of over 36% in April 2000. It is noteworthy that this remarkable revival in turnover in the 10-year Euro Notional futures contract has not been created by the market itself but rather as the result of an initiative of the French banking federation. The liquidity required for raising turnover in this contract has been provided by market-making, conducted by eight French market participants. However, winning new interest in trading this contract has apparently been difficult during recent months because open interest peaked at around 150,000 contracts on average in June 2000.[7] The leap in open interest in this contract from May 2000 is due to a change in the method of calculating open interest by MATIF.[8]

Apart from the revival of the 10-year Euro Notional futures contract, the following decisions made by MATIF immediately after the transition to EMU revealed the intention to intensify competition among European futures exchanges:

### 2.1 Adjustment of products

By launching the two-year E-Note futures contract at the end of January 1999, MATIF rounded off the spectrum of its range of capital market products, so that both MATIF and Eurex now offer interest rate futures contracts for two-year, five-year, 10-year and 30-year government bond maturities.

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4 See Annex 2.

5 See Annex 3.

6 See Annex 4.

7 See Annex 6.

8 Open interest was previously calculated by MATIF as net open interest; since 23 May 2000 it has been calculated as gross open interest.

While turnover and liquidity in the 10-year Euro Notional futures contract have increased since December 1999, liquidity in the two-year and five-year MATIF futures contracts has as yet been insufficient, in contrast to the equivalent Eurex contracts.

### 2.2 Change in contract conditions

In response to two squeezes in deliverable issues of the Euro Bund futures contract (September 1998, June 1999 deliveries), MATIF extended the number of government bonds deliverable in the two-year, five-year and 10-year futures contracts from originally French issues only to include German issues, too, while for the 30-year E-Bond futures contract, designed as a multi-issuer basket, sovereign issues of France, Germany and the Netherlands are deliverable.[9]

As government bond yields during the first half of 1999 clearly moved below the level of the notional contract coupon used for futures contracts at Eurex (6%) and MATIF (5.5%), MATIF decided to lower the notional contract coupon of the 10-year Euro Notional futures contract from 5.5% to 3.5%, and of the five-year Euro futures contract from 4.5% to 3.5% as well.[10] Simultaneously, LIFFE took the same decision by lowering the notional contract coupon of its 10-year Euro Bund futures contract from 6% to 4%.[11]

Despite squeeze risk, Eurex, at the same time, felt compelled neither to open up the deliverable basket of the Euro Bund futures contract to other euro area sovereign issuers nor to lower the notional contract coupon of this contract. Only the contract conditions of the five-year Bobl futures contract were modified in June 2000 by making exclusively German government bonds with remaining terms between 4.5 and 5.5 years eligible for delivery.[12]

Turning from the derivatives markets to the European cash markets, efforts to raise the size of sovereign issues, particularly those of German government bonds, are desirable to avoid the risk of squeezes in deliverable bonds. While the largest size of German 10-year government bonds issued before mid-1999 amounted to EUR 15.3 billion, the size of the last three German equivalent bonds was raised by between EUR 5 and 8 billion to EUR 20-23 billion, thus approaching the size of the largest French 10-year OAT issues amounting to EUR 22 to 25 billion.

In the light of these strategic decisions by Eurex and MATIF, the following section seeks to describe and analyse their consequences for the relationship between European cash and derivatives markets since the transition to EMU.

## 3. Consequences of the transition to EMU for the relationship between European cash and derivatives markets

### 3.1 Squeeze concerns in the Euro Bund futures contract

Before looking at the range of problems faced, it is necessary to define what is meant by a squeeze. In this context, a squeeze is taken to mean a shortage in the cheapest-to-deliver (CTD) bond deliberately caused by market participants so as to make it difficult for other market participants to fulfil their obligations either in the futures market or in the cash and repo market as well. In fact, at no time - including during the September 1998 and June 1999 squeezes - has any failure or a delayed delivery of the Euro Bund futures contract at the contract's delivery date occurred. Nevertheless, squeeze

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9 Two-year E-Note futures contract: dual-issuer basket since March 1999 delivery; five-year Euro and 10-year Euro Notional futures contract: dual-issuer baskets since June 1999 delivery.

10 Adjustment of the notional contract coupon for both futures contracts since June 1999 delivery.

11 Adjustment of the notional contract coupon of this contract since June 1999 delivery. The notional contract coupon was changed again by LIFFE from 4% to 6% on 20 December 1999 for March 2000 delivery.

12 Previous remaining term to maturity for bonds deliverable in the Bobl futures contract: 3.5 to five years.

concerns circulated in the market owing to the confluence of various circumstances, which are examined in detail below. But, if no squeeze has happened yet in the futures market, in which market has a squeeze or a shortage in the CTD bond actually occurred? The following description of the range of problems might give an answer.

### *3.1.1 Range of problems*

In mid-1998, half a year before the transition to EMU, the capital market environment across European cash and derivatives markets may be described as follows:

1. Apart from the Eurex Euro Bund futures contract, no other liquid alternatives traded on other European futures exchanges were available for hedging 10-year European government bonds. Moreover, this futures contract has usually been used in addition for hedging non-government 10-year issues (eg German Pfandbriefe) and 30-year bonds. These issues are not eligible for delivery in the Euro Bund futures contract. Comparing the real deliverable volume of the Euro Bund futures deliverable basket with the potential deliverable volume calculated via the open interest in this contract at peak times reveals that the potential volume exceeded the real deliverable volume of the basket several times over. Then as now, squeeze concerns have been stimulated by this fact.

2. During 1999, yields on 10-year government bonds dropped to a historically low level, far below the level of the notional contract coupon of the Euro Bund futures contract (6%). Only at the yield level of the notional contract coupon is the adjustment of the price differences of the deliverable bonds, caused by coupon and term inequalities, calculated correctly by the conversion factor of each deliverable bond. A deviation from the real yield level to the yield level of the notional contract coupon leads to a bias when calculating the CTD bond at the contract's delivery date. If real yields stay above the level of the notional contract coupon (6%), the conversion factor would determine the deliverable bond with the highest modified duration within the basket as being CTD, while real yields below 6% would determine the bond with the lowest modified duration as being the CTD bond, assuming that all deliverable bonds stay at the same yield.

3. An exceptionally low yield level such as prevailed during the Euro Bund futures squeezes in the September 1998 and June 1999 deliveries may become a problem if the deliverable basket of a futures contract consists of only a few government bonds with very different modified durations. If, however, the price sensitivity of several different deliverable bonds is largely identical, these bonds will probably be able to become CTD after small relative yield changes, so that the deliverable volume of the bonds likely to become CTD will potentially increase. In fact, the deliverable basket of the Euro Bund futures contract, during both squeezes, was composed of few bonds with very different modified durations, so that the probability of a rotation of the CTD bond was low.[13] Furthermore, predicting the CTD bond at the contract's delivery date was easy, due to the bias of the conversion factor when real yields differ from the yield level of the notional contract coupon.[14] Under these circumstances, it was possible for market participants to squeeze the CTD bond in the cash market, particularly when the size of this bond was insufficiently large.

4. The previous discussion on squeezes of the Euro Bund futures contract was mainly focused on the insufficient deliverable volume of the Euro Bund futures basket and the respective CTD bonds. However, another essential problem was given less consideration: the arbitrage mechanism between the cash and derivatives markets did not function smoothly, owing to an insufficiency in the repo market that is the liquidity provider for this arbitrage. Cash-and-carry arbitrage (if the implied repo rate is above repo rate) as well as reverse-cash-and-carry arbitrage (if the implied repo rate is below repo rate) will be possible if the CTD bond is either clearly predictable at the end of the contract or the net basis of the CTD bond is negative. But, obviously, market participants did not exploit the risk-free opportunities for profit. Looking at the single arbitrage steps suggests that one reason for the inadequately

[13] See Annex 8: Euro Bund futures contract: September 1998 and June 1999 deliveries.

[14] When both squeezes occurred, CTD was the bond with the lowest modified duration within the basket.

functioning arbitrage mechanism was the repo market, where the CTD bond was not expected to be redelivered in time.

***Cash-and-carry arbitrage (long CTD bond, short future)***

1. After raising a loan in the repo market, the debtor buys the CTD bond, being cheaper than its fair price, on the cash market, which is then given as collateral to the creditor of the loan (long bond).
2. Simultaneously, the debtor initiates a short futures position (short future).
3. At the contract's delivery date, the debtor can deliver any bond eligible for delivery, but he will deliver the bond he has given as collateral to the creditor in the repo market. If the creditor failed to return this bond to the debtor or were not able to deliver it in time according to the futures settlement date, the debtor would personally fail to satisfy the obligation to deliver this bond into the futures contract. High penalties from the futures exchange would be the consequence.

***Reverse cash-and-carry arbitrage (short CTD bond, long future)***

This arbitrage consists of

1. borrowing the CTD bond in the repo market,
2. selling this bond in the cash market, while simultaneously
3. buying futures contracts.

This arbitrage will work successfully only if arbitrageurs are able to predict with a high degree of probability which bond within the deliverable basket is going to be CTD at the contract's delivery date, because they need to recover the CTD bond they previously sold in the cash market via the futures contract at the delivery date. The last step would be to return the CTD bond to the lender in the repo market after the futures contract's settlement. However, the existence of insufficient fulfilment of repo contracts will cause market participants not to borrow the CTD bond that is "special" in the repo market, so that reverse cash-and-carry arbitrage would not work.

Even though risk-free profitable arbitrage opportunities were offered by the market, most of the market participants were not willing to pick them up because of insufficient fulfilment in the repo market. If the arbitrage mechanism between the cash and derivatives markets had functioned well, price inefficiencies between the futures and cash market would have been unlikely, because the repo market would have provided sufficient liquidity when deviations between real and fair prices of the futures contract and the CTD bond, respectively, had been realised by arbitrageurs.

### *3.1.2 Solutions for the prevention of squeezes*

Different approaches to preventing squeezes in futures contracts can be envisaged. Depending on the market they refer to, cash market, repo market and futures market-based solutions are possible. However, it is worth noting that the solution is not based on just one of the three markets mentioned above. In fact, composite approaches straddling the three markets seem to alleviate or prevent the shortages of the CTD bond.

#### *3.1.2.1 Cash market-based solutions*

Cash market-based solutions are designed to optimise the liquidity of each deliverable bond by increasing the size of a bond. Market participants who attempt to buy large amounts of the CTD bond are likely to be unsuccessful if they try to cause a squeeze in this bond. In this light, the size of the last three German government issues (nos 113513, 113515 and 113516) was increased by between EUR 5 and 8 billion to EUR 20-23 billion. However, it has to be pointed out that despite the high real delivered volume of the CTD bond on the futures contract delivery date, when squeezes occurred no real problems were noticeable in the delivery of the CTD bond.[15]

An alternative approach to avoiding the risk of a squeeze focuses on the price sensitivity of a deliverable bond and seeks to create deliverable baskets with bonds of similar price sensitivities. The measure for the calculation of bond price sensitivity in terms of yield changes is the modified duration,[16] which is determined by the coupon (exogenously fixed according to the prevailing market yield at the issue date) and the term to maturity of a bond. It is quite possible that two bonds, despite being issued on different issue dates, mature on the same date.[17] The difference in the modified durations of these two bonds is then exclusively based on the coupon difference. If, however, two or more deliverable bonds have similar price sensitivities in terms of yield changes, even small relative yield changes between these bonds will be sufficient to cause a rotation in the CTD bond even if there are clear deviations between the market yield level and the level of the notional contract coupon. In that case, the CTD bond would no longer be clearly predictable, so that it would be difficult for market participants to cause a shortage in a CTD bond.

#### *3.1.2.2 Repo market-based solutions*

Approaches to avoiding and alleviating squeeze risk via the repo market are aimed at fulfilling repo contracts in an orderly fashion. Therefore, high penalties for non-fulfilment or delayed fulfilment of repo contracts might be a possible solution to the problem. A more far-reaching approach, however, might be to set up a central counterparty within the repo market in order to avoid the counterparty default risk of repo market participants. Both approaches are suited to activating both the arbitrage mechanism between cash and derivatives markets and the liquidity-providing function of the repo market. Finally, one should bear in mind that longer-term requirements for delivery or delayed delivery of securities could be reduced significantly within Europe by setting up a central European clearing house via which all cross-border transactions would be settled.

#### *3.1.2.3 Futures market-based solutions*

In the aftermath of the squeezes in the Euro Bund futures contract, MATIF and LIFFE made two decisions regarding the futures markets:

1. MATIF extended the deliverable basket of the 10-year Euro Notional futures contract to German government bonds deliverable in the Euro Bund futures contract.
2. MATIF and LIFFE simultaneously changed the notional contract coupon from 5.5% (MATIF)/6% (LIFFE) to 3.5% (MATIF)/4% (LIFFE), respectively.

In the following, the consequences of both steps in terms of contract behaviour will be demonstrated.

*Dual/multi-issuer basket*

The reduction of squeeze risk in an environment of increasing trading volume and open interest by extending the outstanding volume of the 10-year Euro Notional futures basket to include German issues was the main reason MATIF gave for changing the contract specifications of its futures contracts.[18] However, as stated above, it is not the total volume of the deliverable basket but rather a small outstanding amount of the CTD bond - ie the bond mainly delivered at the contract's delivery date - that is one of the primary reasons for squeeze risk. Nevertheless, the extension of the deliverable basket of MATIF futures contracts might prove a quite successful approach for avoiding squeezes. A look at the price sensitivities in terms of yield changes of the deliverable issues in the 10-year Euro Notional futures contract reveals that the combination of German 10-year sovereign

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[15] See Annex 8: Euro Bund futures contract: September 1998 delivery: delivered volume of the CTD bond: 29% of the size; June 1999 delivery: delivered volume of the CTD bond: 35.5% of the size.

[16] Modified duration is defined as the relative change (in %) of the bond's price in terms of a yield change of 1 bp.

[17] See eg DBR 4.75% 04.07.2008, issued on 10.07.1998 and DBR 4.125% 04.07.2008, issued on 30.10.1998.

[18] See MATIF press release: Dual issuer base for Euro Notional and five-year Euro contracts, 27 January 1999. For the June 1999 delivery, the outstanding volume of the Euro Notional futures contract was EUR 127 billion compared with EUR 63 billion of the Euro Bund futures contract.

issues, to be redeemed in January and July, and French 10-year sovereign issues, to be redeemed in April and October, reduces the gap between the modified durations of the deliverable bonds. This, however, leads to a more homogeneous price behaviour of single bonds deliverable in this basket after relative yield changes. Under these circumstances, the CTD bond should change fairly smoothly.

Since the June 1999 delivery, when the 10-year Euro Notional futures basket was redesigned as a dual-issuer basket, a smooth rotation of the CTD bond in this contract has not occurred. Due to the yield spread between German and French government bonds, only French issues have been CTD so far.[19] As long as this yield spread exists, a CTD change as a response to small relative yield changes will, in fact, be impossible. Despite this obvious shortcoming in functioning, the features of this dual-issuer basket, as far as the price behaviour of the deliverable bonds after relative yield changes is concerned, are more positive than those of the 10-year Euro Bund futures contract.

In conclusion, a dual/multi-issuer basket is able to reduce squeeze risk if

1. there are no large yield spreads between different sovereign issues,
2. there is only a small gap between the modified durations of the deliverable bonds, so as to change the CTD bond after only small relative yield changes,
3. each deliverable bond is large in size.

*Change in the notional contract coupon*

As mentioned above, the conversion factor of each deliverable bond will be able to correctly adjust the price differences, due to coupon and term differences of these bonds, if the market yield level equals the yield level of the notional contract coupon. In this ideal scenario, all deliverable bonds will be CTD. As, therefore, several bonds in the deliverable basket might become CTD despite their unequal modified durations, the potential CTD volume at the contract's delivery date will increase, so that the squeeze risk will diminish. Yield deviations from the level of the notional contract coupon will cause a bias by increasing the likelihood that bonds with the highest modified duration within the basket will be CTD if the market yield level stays above the level of the notional contract coupon. On the other hand, if market yields stay below the level of the notional contract coupon, the bond with the lowest modified duration will be CTD.[20] However, the adjustment of the notional contract coupon, as carried out by MATIF and LIFFE in response to the two Euro Bund futures squeezes, will lead merely to a temporary solution of the squeeze problem. As soon as the market yield level moves away from the level of the adjusted notional contract coupon, the bias of the conversion factor will again clearly favour a bond within the basket if the deliverable basket consists of bonds with very different modified durations. The squeeze problem is then once again focused on only one single bond.[21]

Turning to the 10-year Euro Notional futures contract, the bond with the highest modified duration within this basket has been CTD since the lowering of the notional contract coupon from June 1999 deliveries onwards.[22] Since the bond with the highest modified duration is the last issued bond (benchmark bond), this bond, therefore, carries a double function, being CTD and benchmark bond simultaneously. In order to avoid squeezes in this bond - as long as the yield spread between German and French sovereign issues averages 10 to 15 bp, this bond, carrying a double function, will be a French OAT bond - the issuer is forced to place this bond with a high issue size as soon as possible. Given the small amounts of the CTD bond for this contract which have actually been delivered at the contract's delivery date, no shortages have occurred in the CTD bond during the contract periods investigated.[23] This suggests that, compared to the Euro Bund futures contract, the essentially smaller open interest in the Euro Notional futures contract and the large size of French OAT issues might be reasons for this.

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[19] See Annex 8: Euro Notional futures contract; the yield spread averages about 10 to 15 bp in favour of German 10-year government bonds.

[20] Assumption: all deliverable bonds have the same yield.

[21] See Annex 7.

[22] See Annex 8: Euro Notional futures contract June 1999 delivery onwards.

[23] See Annex 8: Euro Notional futures contract, column: Delivered volume.

In conclusion, it should be pointed out that changes in the notional contract coupon will help to alleviate the squeeze risk as long as the adjustment is not too extreme. As for the rest, it should be remembered that, for currently traded contracts, a change in the contract parameters is not possible. Since three contract deliveries, for instance in the Euro Bund futures contract, are traded permanently, the earliest opportunity to adjust the notional contract coupon in this contract is nine months later. In the face of such a large time lag, an adjustment of the notional coupon makes sense and is likely to be successful only if the adjusted coupon covers the yield level of deliverable bonds with a high probability over a long period of time.

### 3.2 Hedge quality of futures contracts and OTC derivatives

Concerning the hedging of German, French and Italian 10-year sovereign issues with 10-year Eurex/MATIF futures contracts or 10-year swaps, the transition to EMU has led to different results for each of the three core euro area countries. The hedge quality of both 10-year futures contracts and 10-year swaps is measured by calculating the daily and weekly correlations of the effective price changes of the 10-year futures/swap contracts and the respective German, French or Italian 10-year benchmark or CTD bonds. The following results should be noted:

1. The transition to EMU, which, in fact, started in May 1998 with the fixing of the bilateral exchange rates between the 11 EMU member countries, has not affected the hedge quality of 10-year Eurex/MATIF futures contracts for German and French sovereign bonds to any great extent. Instead, both the Russian and the LTCM crisis in summer/autumn 1998 and the Euro Bund futures squeezes in September 1998 and June 1999 deliveries did seriously affect the hedge quality of both 10-year futures contracts, especially the Euro Bund futures contract, and 10-year swaps for the corresponding sovereign bonds.[24] On the other hand, prior to the start of stage three of EMU, hedging Italian 10-year government bonds with Italian 10-year swaps proved to be more successful than hedging via 10-year Eurex/MATIF futures contracts.[25] Ever since June 1999 deliveries, however, weekly correlations have shown that 10-year futures contracts of Eurex and MATIF, as opposed to 10-year Euro-swaps, are the better hedge instrument for Italian 10-year government bonds, due to a stabilisation of yield spreads of these bonds in terms of German and French sovereign issues.

2. As far as the hedge quality of 10-year futures contracts compared to 10-year swaps is concerned, the appropriate hedge instruments for German and French 10-year benchmark and CTD bonds during the time period investigated (September 1998 - September 2000) have been 10-year Eurex and MATIF futures contracts.

3. Another interesting question arising in terms of hedging sovereign issues of the core euro area countries is which of the two 10-year futures contracts of Eurex and MATIF has had the better hedge quality during the period under review. Looking at the effective daily price changes of both futures contracts and benchmark bonds, the 10-year Euro Notional futures contract has demonstrated better hedging properties in terms of daily price changes, with the exception of the December 1998 delivery. However, looking at the effective price changes on a weekly basis, the results have been different. Weekly correlations during December 1998, June 1999, December 1999 and June 2000 deliveries show that the 10-year Euro Bund futures contract has been the better hedge instrument at least for German benchmark and CTD issues, although not for French and Italian government bonds.[26]

What are the reasons for different results in hedge quality of the Euro Bund futures contract measured either daily or weekly?

One explanation might be that this contract is used both as a hedge instrument and as a speculative trading tool. Furthermore, due to its tremendous liquidity, the contract is used as a hedge instrument

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[24] See Annex 8: Correlations for September 1998 and June 1999 deliveries.

[25] See Annex 8: Correlations for September 1998 to March 1999 deliveries for Italian benchmark bonds.

[26] See Annex 8: Daily/weekly correlations between German/French benchmark bonds and 10Y EUREX/MATIF futures contracts.

for a variety of domestic and foreign government and non-government issues (eg German Pfandbriefe) with maturities from 10 to 30 years. In both cases, the price of the Euro Bund futures contract changes, although the prices of the respective benchmark or CTD bonds do not necessarily change to the same extent. After the announcement of news causing price movements in the Euro Bund futures contract, these movements might be stronger within a daily trading period. During a weekly trading period, however, these exaggerations in prices recede or even out. Therefore, the hedge quality of the Euro Bund futures contract seems to be better from the weekly point of view.

Daily price movements in the Euro Bund futures contract seem to play an important role in this context. Looking at daily price movements of the respective CTD bonds of this contract, according to which the price of the futures contract itself should normally move, correlations show that prices of the futures contract and the CTD bond have not moved in tandem, leading to visible movements of the net basis of the CTD bond.[27]

In what way has the change in the notional contract coupon of the 10-year Euro Notional futures contract as of June 1999 (from 5.5% to 3.5%) affected hedging of the French benchmark bond?

As long as yields of 10-year government bonds stay above the level of the notional contract coupon (3.5%) of this contract, the deliverable bond with the highest modified duration, ie the last issued bond within the deliverable basket, will, as a rule, be CTD.[28] Therefore, either the French benchmark bond or, assuming that yield spreads between 10-year government bonds of Germany and France do not exist, the German benchmark bond would be CTD in this contract. Since the price of the futures contract should normally follow the price movements of the CTD bond, hedging the respective French benchmark with the Euro Notional futures contract is likely to be more successful than hedging the respective German benchmark bond, which should not be CTD simultaneously, with the Euro Bund futures contract.[29]

## 4. Liquidity, market efficiency and price discovery: a conceptual framework

A financial market is said to liquid when at all times there are a large number of buyers and sellers, such that incoming orders can easily be matched without causing prices to move by a large amount. Liquidity measures should account for both trading volume and concurrent price change. A liquid market absorbs large volume with little price change. Hence, price changes should be relatively invariant to the size of transactions and display limited. An illiquid market yields price concessions on low trading volume. No uniformly accepted single, unambiguous, theoretically correct measure of liquidity exists; all measures suffer one or more limitation. Hence, there are both different concepts of liquidity and different ways of measuring liquidity.[30]

Asset prices change both in response to transitory variations in supply and demand and a result of permanent shifts in the equilibrium value of the asset. In the absence of new information, buy and sell orders would come into the market in a random fashion, leading prices to swing back and forth without any trend. As new information arrives, however, prices are driven to a new level. In these instances, big price movements can occur even on small volume trading. This is where the distinction between liquidity and efficiency becomes most significant.[31]

The critical factor in the analysis is the recognition that price changes are not all alike in origin and significance. Random variations in price are noise and liquid markets keep those random variations tight and minimal, regardless of the size or number of transactions.

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[27] See Annex 8: Correlations of the CTD bonds of the Euro Bund futures contract.

[28] Assumption: the yields of all deliverable bonds are the same.

[29] This result is supported by comparison of the daily/weekly correlations between the Euro Notional futures contract/Euro Bund futures contract and the respective benchmark bonds within each futures contract from June 1999 deliveries onwards.

[30] Cf Bernstein (1992), who concludes that “no single measure tells the whole story about liquidity” (p 61).

[31] Dimson and Mussavian (1999) provide a clear presentation of the distinction between market efficiency and liquidity.

### 4.1 Price change, volatility and measurement of market efficiency

Price efficiency is synonymous with accurate reflections of equilibrium values. Prompt price changes in response to new information are essential as they are the key signal to fundamental values and expectations. An efficient market should let prices move fast when market participants' perception changes, hence price changes tend to be discontinuous. As a result, efficient markets may not attract large number of active investors, especially knowledgeable investors who are able to profit from pricing errors. Yet, liquid and efficient markets both need a large number of active interested and investors. This is where tension arises between liquidity and efficiency or, in terms of market participants, between noise traders and information traders. In an efficient market information-motivated shifts in supply and demand should have a free rein impact on prices; conversely, in a liquid market random swings in supply and demand should have a minimal impact on price. Noise traders, acting on imperfect information, will frequently push prices away from equilibrium values. The resulting undervaluation or overvaluation attracts information traders (arbitrageurs), who push prices back to equilibrium values. Therefore the dynamic properties of price changes and the price effects of trading need to examined. Ideally a theoretical model of prices and price revisions due to trading would provide a framework to decompose price changes into transitory and permanent parts.

To measure informational efficiency in two different markets, financial economists look at the so-called lead-lag relationship. The basic intuition is that in an efficient frictionless market, the prices of two identical assets should be identical (law-of-one-price) - therefore perfectly correlated - and instantaneously reflect all available information.[32] A lead-lag relationship, with one price adjusting earlier than the other one, will develop if market imperfections are present. To detect the presence of a lead-lag relationship, the first task would be to model the intertemporal and cross-market characteristics of returns in both market. Additional insight into the informational efficiency of the two markets can be obtained by comparing the time series properties of volatilities. If returns are driven by information arrival and the rate of information arrival is non-constant, possibly stochastic, then volatility will evolve over time.[33] For example, periods with few news releases might be followed by periods with fast information arrival inducing changes in return volatility. Two efficient and frictionless markets trading the same asset and receiving the same information shocks should exhibit a similar volatility pattern. If, however, volatility patterns differ across the two markets, then we may conclude that either (i) information flows to one market prior to the other, or (ii) the two markets receive the same information, but differ in their speed of adjustment to information shocks. As the former proposition is very difficult to test, one would normally assume that the two markets receive the same information and examine the differences in volatility adjustment mechanisms by employing a model of time-varying volatility.

### 4.2 Dynamic analysis of price discovery

The endogenous character of the pattern of price changes and activity and the asymmetric information revelation across markets induce lagged effects on the adjustment process driving market price discovery. To take into account the statistical properties of financial series (including their non-stationarity), the vector error-correcting model (VECM) seems a suitable multivariate framework for modelling interest rate dynamics. Vector autoregression (VAR) models have already been widely introduced into the market microstructure literature.[34]

Let $Z_t$ be a vector of (nx1) of financial (eg interest rates) series, integrated of order 1 (eg I(1)) and with mean 0, for simplicity, and assume that the rank of cointegration is m, namely there exists a matrix A (nxm) of rank m - the number of cointegrating vectors - such that the linear combinations $W_t \equiv A'Z_t$ are stationary (eg I(0)) vector of variables. It follows that changes in $Z_t$ admit the VAR representation

[32] See, for example, Dimson and Mussavian (1998).

[33] See Tauchen and Pitts (1983), Andersen (1993).

[34] See Hasbrouck (1993).

$$\Delta Z_t = \Gamma A' Z_{t-1} + \sum_{i=1}^{q} \Gamma_i \Delta Z_{t-i} + \varepsilon_t^{\Delta Z},$$
$$\text{cov}(\varepsilon_t^{\Delta Z}) = \left\langle \sigma_{\Delta Z}^2 \right\rangle \tag{1}$$

where $\Gamma$ is a an (mxn) matrix, $\{\Gamma_i\}$ are (nxn) matrices and < · > indicates a (nxn) diagonal matrix. In our analysis $Z_t$ may also include stationary (eg I(0)) variables; matrix $\Gamma$ would be adjusted accordingly to take this case into account.

The element of $Z_t$ can be explained in terms of a smaller number (n-m) of I(1) variables, $F_t$ , called common factors, plus a vector of I(0) (stationary) components, $T_t$:

$$Z_t = A_1 F_t + T_t \tag{2}$$

One can estimate such a common factor decomposition from the VECM (1); to identify the long-run common factors, one has to impose that $F_t$ be the linear combination of the observed time series vector of variables $Z_t$ [35]

$$F_t = \Gamma^{*\prime} Z_t \tag{3}$$

We identify $P_t = A_1 F_t$ as the permanent (long-run) component of $Z_t$, with factor loadings represented by matrix $A_1$. Analogously, the transitory part, $T_t$, can be expressed in terms of a common set of factors, $W_t$, again constructed as a linear combination of the observed time series vector of variables $Z_t$, $W_t = A' Z_t$, where $T_t = A_2 W_t$, with factor loadings represented by matrix $A_2$. As a result, we can summarise the permanent transitory decomposition as

$$P_t = A_1 F_t = A^* (A^{*\prime} \Gamma^*)^{-1} F_t$$
$$T_t = A_2 W_t = \Gamma (A' \Gamma)^{-1} W_t \tag{4}$$

where A' is the matrix of cointegrating vectors; $\Gamma$ is the matrix of the contribution of the "correction" term in the VAR, given by the (transitory) deviation, $W_{t-1}=A'Z_{t-1}$, from the stationary (long-run) equilibrium level, on the changes of $Z_t$; A* and $\Gamma$* orthogonal matrices to A and $\Gamma$, respectively (eg A'A*=0 and $\Gamma$'$\Gamma$*=0).

It is convenient to provide an AR representation for the factor decomposition written down in equations (2)-(4):

$$\begin{pmatrix} a(L) & b(L) \\ c(L) & \mathrm{d(L)} \end{pmatrix} \begin{pmatrix} \Delta P_t \\ T_t \end{pmatrix} = \begin{pmatrix} \varepsilon_t^{\Delta P} \\ \varepsilon_t^{T} \end{pmatrix},$$
$$\text{cov} \begin{pmatrix} \varepsilon_t^{\Delta P} \\ \varepsilon_t^{T} \end{pmatrix} = \begin{pmatrix} \Omega_{\Delta P} & 0 \\ 0 & \Omega_{\mathrm{T}} \end{pmatrix} \tag{5}$$

where $\Delta P_t$ denotes the time changes of the permanent (long-run) component of decomposition (2) and a(L) to d(L) are polynomials in the lag operator; the error terms, $\left(\varepsilon_t^p, \varepsilon_t^x\right)$, are supposed to be uncorrelated (eg the covariance matrix of disturbances is diagonal).

### 4.3 Dynamic decomposition through the VAR impulse response function

The AR representation (5) allows a very general dependence of the decomposition $Z_t$ into permanent and transitory components as a function on contemporaneous and past shocks. However, a restriction

[35] See Gonzalo and Granger (1995) for a formal proof.

on the polynomial lags structure (multipliers) follows from equation (3); it requires that $T_t$, the transitory component, does not Granger-cause $P_t$, the permanent component, in the long run (eg at frequency 0)

$$b(1) = 0 \tag{6}$$

The effects of shocks on the decomposition can be computed from the impulse response of an AR model by transforming (4) into the following vector moving average (VMA) representation:[36]

$$\begin{pmatrix} \Delta P_t \\ T_t \end{pmatrix} = \begin{pmatrix} \alpha(L) & \beta(L) \\ \gamma(L) & \delta(\mathrm{L}) \end{pmatrix} \begin{pmatrix} \varepsilon_t^{\Delta P} \\ \varepsilon_t^{T} \end{pmatrix} \tag{7}$$

To illustrate the usefulness of the VMA form, consider the equation for the long-run changes in more detail

$$\Delta P_t = \sum_{j=0}^{\infty} \alpha_j \varepsilon_{t-j}^{\Delta P} + \sum_{j=0}^{\infty} \beta_j \varepsilon_{t-j}^{T} \tag{8}$$

In words, long-run changes are infinite sums of past innovations $\left(\varepsilon_t^{\Delta P}\right)$ and $\left(\varepsilon_t^{T}\right)$. The effect of unit innovations on the *change* in the long-run component k periods ahead is measured by $\alpha_k$ and $\beta_k$ , respectively; the effect of unit innovations on the short-run component k period ahead is measured by $\gamma_k$ and $\delta_k$, respectively

$$T_t = \sum_{j=0}^{\infty} \gamma_j \varepsilon_{t-j}^{\Delta P} + \sum_{j=0}^{\infty} \delta_j \varepsilon_{t-j}^{T} \tag{9}$$

Thus the coefficients of the VMA are exactly the desired impulse responses. The effect of a unit shock on the *level* of the permanent component k periods ahead is measured by partial sums of the impulse response:

$$p\varepsilon_{\Delta p}(k) = \sum_{j=0}^{k} \alpha_j , p\varepsilon_x(k) = \sum_{j=0}^{k} \beta_j \tag{10}$$

the total long-run effects of shocks are easily determined as limits of the partial sums as $k \to \infty$:

$$p\varepsilon_{\Delta p}(\infty) = \sum_{j=0}^{\infty} \alpha_j , p\varepsilon_x(\infty) = \sum_{j=0}^{\infty} \beta_j \tag{11}$$

Cochrane (1988) notes that this definition of the long-run effects of innovations is unique and independent of any particular decomposition of the price process into permanent and transitory parts (see De Jong et al (1996)).

### 4.4 "Noise" and "fundamental" value as decomposition of price change into transitory and permanent component

The impulse responses (8)-(9) provide all necessary information for decomposing $Z_t$ into permanent and transitory components. Such a decomposition can be interpreted as an identification technique that separates "fundamental" factors, eg variables with a long-lasting effect on prices, from "noise" effects; the former measuring the efficient component of price changes, the latter the deviation of the

[36] Sims (1980) popularised the use of such a representation for VAR models.

observed price from the efficient price.[37] This approach is a natural extension of the Hasbrouck (1993) methodology, which decomposes an asset price into a random walk (permanent) component and a stationary component around the random walk, with the former representing the underlying equilibrium (efficient) price of the security in which all public information is reflected and the second, transitory, component generally regarded as the pricing error,

Hasbrouck (1993) proposes using the standard deviation of "efficient" and "noise" price components

$$\begin{aligned} \text{var}(\Delta P_t) &= \left(\sum_{j=0}^{\infty}\alpha_j\right)\Omega_{\Delta P}\left(\sum_{j=0}^{\infty}\alpha_j\right)' + \left(\sum_{j=0}^{\infty}\beta_j\right)\Omega_T\left(\sum_{j=0}^{\infty}\beta_j\right)' \\ \text{var}(T_t) &= \left(\sum_{j=0}^{\infty}\gamma_j\right)\Omega_{\Delta P}\left(\sum_{j=0}^{\infty}\gamma_j\right)' + \left(\sum_{j=0}^{\infty}\delta_j\right)\Omega_T\left(\sum_{j=0}^{\infty}\delta_j\right)' \end{aligned} \tag{12}$$

as a summary measure of the "quality" of a securities market. Intuitively they reflect how closely observed market prices track the "efficient" price on average. He suggests a market quality measure (mqm) of a noise-to-signal ratio type of indicator, namely the pricing error variance of the security divided by the "efficient" price change:

$$mqm = \sqrt{\frac{VARIANCE(T_t)}{VARIANCE(\Delta P_t)}} \tag{13}$$

The mqm indicator can be thought of as a measure of market efficiency for the price-discovery process. In practice, several factors can impinge upon the speed with which the process takes place, such as, among other things, transaction costs (large bid-ask spreads that prevent crossing the trade at the mid-price) as well as the lag with which securities prices adjust to the arrival of new information. In this sense it is understood as a "dynamic" measure of transaction costs that generalises the traditional Roll's estimator (Roll (1984)). Under Roll's special assumption VARIANCE($T_t$) would be equal to half the realised bid-ask spread. A larger variance in the noise component would signal a rising uncertainty in the price discovery and declining informational efficiency.

## 5. Data description and statistical properties of interest rates in the euro area

The measurement technique presented in the previous section is used to assess bond cash market efficiency in the euro area. We concentrate our study on the long-term segment of the market (10-year maturity), focusing on the swap and government bond market benchmark yield. We confine our estimates to the largest government bond markets of the euro area (France, Germany and Italy) using the US and UK markets as a benchmark reference.

To achieve this goal we have assembled a data set of market interest rates covering the main segments of the euro area, including the interbank market (three-, six- and 12-month interest rate), the short futures rate (Eurex three-month futures rates up to one year maturity), the long futures price (on the 10-year bund), swap rates (with a maturity of two, three, five, seven and 10 years), Treasury benchmark (Bund, OAT and BTP yields with a maturity of three, five and 10 years) and corporate benchmark (10-year);[38] the data are daily quotes and cover the period from 3 January 1990 to 31 August 2000. Table 1 provides summary statistics over the period used in the estimation. Chart 1

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[37] Other decompositions into permanent and transitory components are also possible. Hasbrouck (1993), who adopts the Beveridge and Nelson (1981) approach, shows that the Beveridge-Nelson decomposition gives a lower bound for the variance of the stationary price part among all possible decompositions.

[38] Data come from Datastream and Bloomberg; BTP benchmark yields are calculated by the Bank of Italy.

reports some of the spread for the larger countries in the euro area vis-à-vis the 10-year German bund yield.

Before going through the econometric estimation, we check some statistical properties of the series used in this paper. We first consider long-run properties for the level of interest rates, that is non-stationarity and cointegration; this is required since many papers have given evidence of non-stationary behaviour of interest rates.[39] In that case dealing with rates in level calls for a proper econometric handling. At this stage, we have to restrict our attention to a five series system $Z_t=(\Sigma_t,S_t,Y_t,L_t,R_t)$ of interest rate levels; these rates are as defined as follows:

$\Sigma_t$ = implied forward rates in the three-month futures yield on the Euribor

(average of four consecutive three-month delivery dates).

$S_t$ = 10-year interest swap rate on the euro.

$Y_t$ = 10-year yield to maturity on German bund.

$L_t$ = 12-month interbank rate (Libor) on the euro.

$R_t$ = three-month interbank rate (Libor) on the euro.

Standard unit-root tests (as reported in Table 2, Panel A) allow us to conclude that interest rates in our sample can be considered non-stationary. Hence the framework laid out in the previous section provides a meaningful tool for assessing the extent to which changes in fundamental values vs the "noise" (idiosyncratic) component have impinged upon interest rates in the euro area. The following yield spreads are used for dynamic analysis:

(St - Yt , Σt - Rt , Rt - Lt , Lt - Yt)

These include a 10-year swap spread, $S_t$ - $Y_t$ , a forward term spread, $\Sigma_t$ - $R_t$, a short-term rate spread, $R_t$ - $L_t$, and a long-term yield spread, $L_t$ - $Y_t$. In Chart 2 we plot the 10-year swap spread vis-à-vis the German bund; it displays a fair amount of volatility and an upward trend seems to have appeared since the start of EMU; a corporate bond spread displays a similar pattern. Although we expect to find yield spreads mostly stationary, unit-root tests for spreads (not reported) lead to a somewhat less clear-cut conclusion than on levels; all in all, the stationary component in the spreads does appear to be predominant at the significance level of 1%.

This is confirmed by the Johansen Maximum Likelihood (JML) procedure for the testing of cointegration relationships. For a VAR of order 7 (order suggested by the Akaike information criterion) at the significance level of 1% only one cointegrating vector appears to be selected by the trace test for cointegration rank (Table 2, Panels B-C). However, at the 5-10% significance level we could not reject the hypothesis of two cointegrating vectors. With two cointegrating vectors out of five variables there are 3 I(1) common factors driving the long-term dynamics of the interest rates. In addition, the (unrestricted) cointegrating vector coefficients nearly add up to zero, which would be consistent with the hypothesis that the long-run relationship among interest rates can be restricted to involve the information content of spreads only; a formal $\chi^2$-square test of the unit restriction would not be rejected at the 1% significance level for both cointegrating vectors.

The JML procedure for the testing of cointegration relationships is applied to a sample of 10 bond yields in the G5 countries (Germany, France, Italy, the United Kingdom and the United States), as reported in Table 5; the data consist of 2,090 daily observations from 1993:1 to 2000:365. For a VAR of order 7 (order suggested by the Akaike information criterion) at the 5% significance level we cannot reject the hypothesis of only one cointegrating vector; as a result there are four common I(1) factors driving the whole system of interest rates in the long run and one common I(0) factor, the transitory component, capturing the common source of deviations from the permanent component ("mispricing" effect).

[39] See, for example, Hall et al (1992), Engsted and Taggart (1994), Drudi and Violi (1996) and Avouyi-Dovi and Jondeau (1999).

### 5.1 Econometric estimates of the determinants of bond market liquidity and price efficiency in the euro area

Cointegration and stationary spreads allow us to turn to a simple univariate equation estimate defining the long-run relationship between swap spread and forward spread, short-term spread and long-term spread:

$$S_t - Y_t = \lambda_0 + \lambda_1(\Sigma_t - R_t) + \lambda_2(R_t - L_t) + \lambda_3(L_t - Y_t) + \varepsilon_t^{SY} \quad (14)$$

The information content of the forward spread for the 10-year swap spread and the slope of the yield curve (short and long) are quite significant determinants of the swap spread; the adjusted $R^2$ of the regression is relatively high (0.34; Table 3) and the estimated slope parameters are significantly positive, although very far from 1 (actually close to zero or negative for the short-term slope of the yield curve). Deviation from 1 for the slope parameters (and zero for the constant term) in the regression does not imply immediate rejection of the no-arbitrage-restriction characterising the estimated model; it may simply be a consequence of the shorter horizon of the forward spread (one-year as against 10-year horizon) entering the estimated regression. However, while the estimated relationship seems fairly robust in recent years,[40] there are still clear signs of heteroskedasticity and autocorrelation in the regression residuals. A Garch (1,1) estimation of the conditional volatility process[41] for the swap spread equation (14)

$$(\sigma_t^{SY})^2 = \mu_0 + \mu_1(\sigma_{t-1}^{SY})^2 + \mu_2(\varepsilon_{t-1}^{SY})^2 \quad (15)$$

suggests that estimated time-varying volatility has been definitively higher since the beginning of EMU compared to the rest of the sample (see Chart 3). Most of the "excess volatility" does not seem to originate from increased forward and term spread volatility, rather it appears to reflect additional "noise" specific to the swap spread. We provide evidence for this hypothesis by extending equation (12) to a "state-space" (Kalman filter) specification in which the forward rate spread is only imperfectly observed - the 10-year consecutive forward rates are not traded in the market for the outer horizon - and the "true" forward spread $\Sigma_t^*$- $R_t$ follows an AR(1) process

$$\begin{aligned} S_t - Y_t &= \lambda_0 + \lambda_1(\Sigma_t^* - R_t) + \lambda_2(R_t - L_t) + \lambda_3(L_t - Y_t) + \varepsilon_t^{SY} \\ \Sigma_t - R_t &= \phi_0 + \phi_1(\Sigma_t^* - R_t) + \varepsilon_t^{\Sigma R} \\ \Sigma_t^* - R_t &= \varphi_0 + \varphi_1(\Sigma_{t-1}^* - R_{t-1}) + \varepsilon_t^{\Sigma^* R} \end{aligned} \quad (16)$$

The fit of the swap spread "measurement" equation improves substantially (R-squared increases to 0.99) and estimated coefficients for the spreads are much larger than those estimated for equation (14).

Swap spread equation errors increase significantly in the first six months of this year, especially at times when the swap spread widened during the second quarter of the year, in the wake of the UMTS mobile phone licence auction in Germany.

All in all, the econometric evidence suggests that, at least in part, fluctuations in the euro swap spread vis-à-vis the bund, over and above the movements related to the changes in the term structure of interest rates, may be due to idiosyncratic movements in the German government 10-year bond yield; only the French OAT has partially kept pace with the growing German swap spread, while the Italian swap spread has remained fairly stable.

A measure of the extent to which such fluctuations have affected efficient price discovery for euro interest rates can be gauged by estimating the parameters of the VECM (1); such estimates allow us to compute the impulse response associated with the system of equations (7); finally the market quality indicator, mqm, can be obtained from equation (13).

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[40] Eliminating the observations for 1999-2000 (ie the EMU sub-sample) from the data set little changed the results of the estimation, leaving the explanatory power of the forward spread almost identical.

[41] See for example Bollerslev, Chou and Kroner (1992) for details of Garch application in econometric finance.

Table 4 reports the calculated efficiency measures for each interest rate evaluated for several sub-samples. There is a clear worsening of "market quality" as witnessed by the increase in the mqm indicator from 1998 to 1999; it almost doubles for all interest rates but the average three-month futures rate. For the 10-year bund the mqm indicator continues to rise (from 0.019 to 0.026) signalling a further slight worsening in mispricing. Conversely, the 10-year swap rate mqm remains unchanged.

### 5.2 Comparing bond market liquidity and price efficiency in G5 countries: euro area vis-à-vis the United Kingdom and the United States

Table 6 reports results of the permanent-transitory decomposition of 10-year bond yields for the G5 countries (France, Germany, Italy, the United Kingdom and the United States; see Table 5 for some descriptive statistics). The standard deviation of the stationary part (transitory component) provides a measure of the extent of the "mispricing" (liquidity effect) as a result of deviations from the "fundamental" value (permanent component) of current bond yields. The proportion to the latter standard deviation (mqm indicator) shows a worsening of liquidity across countries in 1999 compared to 1998, especially in Germany and Italy (from 9 to 13.6 and 5.9 to 8.2 respectively); to a lesser extent the decline in market liquidity also affects the United Kingdom and, to a very limited scale, even the United States. Such a global phenomenon may be partly related to the consequences of the Russian/LTCM liquidity crisis; this is confirmed by inspecting the standard deviation of the common liquidity risk factor,[42] which exhibits a sharp increase in August 1998 (Chart 4).

It is worth noting that in 1999 the deterioration of market liquidity is caused by the increase in the standard deviation of the transitory part, whereas the standard deviation of the fundamental value (permanent component) is virtually unchanged across countries. The worsening of liquidity conditions, according to the mqm indicator, seems to have receded during 2000, when liquidity measures reverted to levels below the pre-crisis level. For Germany, the United Kingdom and the United States, the differences in the level of mqm is attributable to the standard deviation of the transitory part, a sort of absolute measure of "mispricing"; in Germany this measure is 5-16 times higher than in the United Kingdom and the United States, as evaluated in 2000. Italy displays an absolute level of its bond market liquidity measure much closer to that of the United Kingdom and the United States, eg a significantly lower "mispricing" than Germany and France. This is a persistent feature over the time span of our sample and it might be related to the advanced trading infrastructure and market participation developed by the Italian MTS in the early 1990s.

All in all relative liquidity measures confirm the high degree of bond yields convergence across the G5 countries, especially across the largest economies of the euro area. The United Kingdom and the United States bond markets still maintain a positive liquidity differential, as measured in relative terms, with respect to those of continental Europe.

Global convergence in bond yield fundamental values, especially vis-à-vis the United States (see Chart 5), broadly explains recent trends of liquidity convergence. According to the estimated VECM for the G5 countries, implied equilibrium 10-year bond yields - ie estimated permanent (price-efficient) components - only differed by less than 50 basis points at the end of 2000 between the euro area (taken as a simple average of French, German and Italian government bond market rates) and the United States. Long-run equilibrium rates in the United States have been persistently above those of the euro area since 1997; similarly, euro area equilibrium 10-year rates are estimated to be just over 50 basis points above those of the United Kingdom. Consequently, euro area 10-year bond rates are estimated at the end of last year to have been just over 25 basis points above their equilibrium level; UK rates were almost 75 basis points above their long-run equilibrium value; conversely, US rates were some 20 basis points below their long-run equilibrium level (Chart 6).

[42] The standard deviation refers to the simulated volatility of a GARCH(1,1) model for the common stationary factor, $W_t$, implied by the VAR-based decomposition in equation 4.

## 6. Concluding remarks

Notwithstanding increasing money and bond market integration in continental Europe since the launch of the euro, a reliable government yield curve is still struggling to establish itself. Market participants have responded to the introduction of the new currency by concentrating liquidity on Eurex's Euro Bund futures contract. The rapid expansion of the Eurex capital market futures contracts in the last few years and an active repo market have reaffirmed the benchmark prominence of German government bonds. However, the budgetary developments in Germany - implementation of the Stability Pact, tax reform resolution and the sale of UMTS mobile phone licences - may further reduce the already narrow base of deliverable bonds in the existing futures markets. The disproportion of futures and cash markets, if not properly counteracted from the supply side, could leave the euro area government bond market less liquid than it might otherwise be.

In the run-up to monetary union, there were far-reaching changes on OTC and exchange-traded derivatives markets in the core euro area countries (France, Germany and Italy). OTC derivatives trading, especially interest rate swaps, has expanded significantly both worldwide and at the European level when compared with exchange-based derivatives trading. This trend seems to be driven mainly by a rising demand for hedging instruments on spread products like agency and corporate bonds. Liquidity on European exchange-traded derivatives markets has become concentrated on a handful of futures exchanges, but this trend has not been evident on European cash and repo markets. With the transition to EMU, the European exchanges have intensified their efforts to create a joint market for exchange-traded European assets through mergers and cooperative ventures. For the cash markets, this intention has not yet been successfully carried out. In the case of exchange-traded derivatives, however, market participants made their decision at an early stage by bundling liquidity: LIFFE and Eurex have established themselves as the most liquid trading place for money market derivatives and capital market derivatives, respectively.

Electronic trading of derivatives has increased substantially on futures exchanges in Europe. By concentrating liquidity on a handful of exchanges, another decision has been made by the market: the electronic trading of derivatives, with the additional aim of organising cash and repo trading on a joint electronic trading platform. Although a liquid, electronically driven market for European government bonds with a connected repo trading facility has been created by EuroMTS, London, the Europe-wide landscape of trading opportunities for fixed income products remains fairly fragmented. A considerable share of the secondary market activity in European government bonds is still concentrated on the domestic market. The development in the last two years of electronic inter-dealer bond markets in several European countries (Belgium, France, the Netherlands, Portugal and, more recently, Germany), based on the Italian MTS trading system, has so far only partly changed the overall picture of country-based concentration of market liquidity. Clearly, the expansion of the MTS platform across Europe and the rapid development of EuroMTS bode well for the prospect of strengthening market integration in the euro area, but new challenges are still ahead for the successful establishment of a single cash bond market in Europe.

Concentration of trade in capital market futures on Eurex has produced positive effects in terms of liquidity. However, concerns about squeezes in capital market futures have not been dispelled, especially under certain stressed market conditions (flight to quality, reduced supply of on-the-run benchmark securities, scarcity of deliverable securities, etc). Even though no squeezes in capital market futures have actually occurred so far, there are recognisable deficiencies in the fulfilment of cash and repo market transactions, which may reinforce squeeze concerns. The success of an electronic trading platform in Europe (like EuroMTS) will, therefore, mainly depend on how fixed income products and their derivatives as well as the repo market are integrated on this platform and whether it will be able to eliminate counterparty risk. So far the integration has taken place on a very limited scale; the repo trading facility available on the Italian platform of MTS is the only case in point.

Since the start of monetary union, yield spreads have widened in the euro area. Liquidity considerations are becoming more important in the context of EMU, where investors are no longer confined to their domestic markets by either exchange rate concerns or restrictive regulations and investment rules. Several determinants of liquidity seem to be at play: segmentations related to legal and regulatory differences; increased basis risk related to the quality of hedging bond positions in the futures markets; variable access to an active repo market and obstacles in the cross-border management of collateral; differences in bid-ask spreads across markets. While such factors are likely to be relevant in explaining euro area yield spreads, their relative importance is difficult to assess.

Changing segmentation is bringing about adjustments in the pricing differentials across markets and variations in bonds' liquidity, thus affecting the process of price discovery. Price formation in the bond markets has been hit by shifting liquidity and trading activity; market participants are reassessing relative bond values in the euro area as a result of changes in the market structure and supply.

Preliminary econometric evidence confirms that fluctuations in yield spreads across the European Union contain a significant transitory part, which can be identified as a source of "mispricing" (ie a temporary deviation from fundamental values). According to the liquidity indicator estimated in this paper the level of "mispricing" temporarily increased around the euro launch date. This increase appears by and large to have been reversed in 2000, as the impact of the launch of the euro on market participants' learning process kept on unfolding and the global implication of the Russian/LTCM crisis receded. The reversal of liquidity conditions during 2000 brought liquidity measures back to levels below that of the pre-1998 crisis.

Liquidity measures display a high degree of convergence across the G5 countries. However, according to our indicator of relative market liquidity, UK and US bond markets still maintain a positive liquidity differential with respect to those of continental Europe. Within the euro area, relative measures of bond market liquidity are now fairly similar. Italy, however, displays an absolute level of its bond market liquidity indicator (standard deviation of the transitory component) much closer to the estimates for the UK and US markets, ie significantly higher than the level estimated for Germany and France. This might be related to the advanced trading infrastructure and market participation developed by the Italian MTS since the early 1990s.

All in all, relative liquidity measures confirm the high degree of bond yield convergence across the G5 countries, especially across the largest economies of the euro area. UK and US bond markets still maintain a positive liquidity differential, measured in relative terms, with respect to those of continental Europe. Global convergence in bond yield fundamental values broadly explains recent trends of liquidity convergence. At the end of 2000, implied equilibrium 10-year bond yields only differed by less than 50 basis points between the euro area and the United States, whose long-run equilibrium rates have been persistently above those of the euro area since 1997. Similarly, euro area equilibrium 10-year rates are estimated to have been just over 50 basis points above those of the United Kingdom. Consequently, euro area 10-year bond rates are estimated at the end of last year to have been just over 25 basis points above their equilibrium level at the end of last year. UK rates were almost 75 basis points above their equilibrium values. Conversely, US rates were some 20 basis points below their long-run equilibrium level.

Table 1

**Euro short and long interest rate**[1]

daily data

| 1993:1<br>2000:365 | Descriptive statistics | | | | |
|---|---|---|---|---|---|
| | $S_t$ | $Y_t$ | $L_t$ | $R_t$ | $Sigma_t$ |
| mean | 6.16 | 5.83 | 4.43 | 4.39 | 4.4 |
| median | 6.15 | 5.86 | 4.00 | 3.69 | 4.06 |
| standard deviation | 0.94 | 0.99 | 1.09 | 1.48 | 1.08 |
| min | 4.03 | 3.63 | 2.69 | 2.59 | 2.66 |
| max | 8.03 | 7.77 | 5.99 | 9.12 | 7.37 |
| **Correlations** | | | | | |
| $S_t$ | 1 | 0.99 | 0.68 | 0.55 | 0.69 |
| $Y_t$ | | 1 | 0.67 | 0.57 | 0.68 |
| $L_t$ | | | 1 | 0.89 | 0.95 |
| $R_t$ | | | | 1 | 0.91 |
| $Sigma_t$ | | | | | 1 |

[1] German rates before 1999.

$Sigma_t$ = implied forward rates in the three-month futures yield on the Euribor (average of four consecutive three-month delivery dates). $S_t$ = 10-year interest swap rate on the euro. $Y_t$ = 10-year yield to maturity on German bund. $L_t$ = 12-month interbank (Libor) rate on the euro). $R_t$ = three-month interbank (Libor) rate on the euro.

Table 2

| **Panel A** | **Unit root tests** | | | | |
|---|---|---|---|---|---|
| **1993:1<br>2000:365** | $S_t$ | $Y_t$ | $L_t$ | $R_t$ | $Sigma_t$ |
| ADF | –1.16 | –1.31 | –0.05 | –1.04 | –0.94 |
| (P-values) | *0.92* | *0.89* | *0.99* | *0.93* | *0.95* |
| PHILLIPS | –5.51 | –4.61 | 1.56 | –3.02 | –2.76 |
| (P-values) | *0.78* | *0.85* | *1.00* | *0.93* | *0.95* |
| WTD-SYM | –1.48 | –1.62 | –0.54 | 1.85 | –0.11 |
| (P-values) | *0.89* | *0.85* | *0.99* | *1.00* | *1.00* |
| (Number of lags) | 12 | 12 | 28 | 20 | 6 |
| **Panel B** | **Cointegration vectors: Johansen ML proc.** | | | | |
| 1° cointegration vector | 1.00 | –1.06 | –0.17 | –0.07 | 0.20 |
| 2° cointegration vector | 1.00 | 5.31 | 46.78 | –7.93 | –45.66 |
| Eigenvalues | 0.0363 | 0.0082 | 0.0078 | 0.0032 | 0.0003 |

| **Panel C** | **Cointegration rank test** | |
|---|---|---|
| *No of cointegration vectors: r* | *Trace test* | *P-values* |
| HO: r=0 | 157.07 | 0.000 |
| HO: r<=1 | 54.26 | 0.054 |
| HO: r<=2 | 31.27 | 0.103 |
| HO: r<=3 | 9.62 | 0.505 |

## Table 3
**Econometric estimates**

| Sample: 1993:1 2000:365 | Constant | $Sigma_t$-$R_t$ | $R_t$-$L_t$ | $L_t$-$Y_t$ | ADJ.$R^2$ | SER | DW | LOG-LIK |
|---|---|---|---|---|---|---|---|---|
| **OLS** | | | | | | | | |
| $S_t$-$Y_t$ | 0.43 | 0.0893 | -0.0196 | 0.06937 | 0.34 | 0.106 | 0.13 | 2334 |
| *T-Statistic* | *103.6* | *12.3* | *-3.08* | *26.9* | | | | |
| *Standard Error* | *4.1.E-03* | *7.3.E-03* | *6.3.E-03* | *2.6.E-03* | | | | |
| **GARCH** | | | | | | | | |
| $S_t$-$Y_t$ | 0.30 | -0.03329 | -0.107 | 0.0153 | 0.70 | 0.042 | 0.54 | 3670 |
| *T-Statistic* | *167.4* | *-12.7* | *-68.9* | *13.9* | | | | |
| *Standard Error* | *1.8.E-03* | *2.6.E-03* | *1.6.E-03* | *1.1.E-03* | | | | |
| Volatility param. | $mu_0$=0.234.E-03 | $mu_1$=0.697 | $mu_2$=0.336 | | | | | |
| *T-Statistic* | *9.3* | *17.1* | *15.6* | | | | | |
| *Standard Error* | *2.5.E-05* | *4.1.E-02* | *2.1.E-02* | | | | | |
| **KALMAN FILTER** | | | | | | | | |
| $S_t$-$Y_t$ | 0.00177 | 0.5507 | 0.697 | 0.452 | 0.99 | 0.015 | 0.56 | 12560 |
| *T-Statistic* | *13.3* | *3328.8* | *4199.9* | *3545.9* | | | | |
| *Standard Error* | *1.3.E-04* | *1.7.E-04* | *1.7.E-03* | *1.3.E-04* | | | | |
| Volatility param. | $mu_0$=0.265.E-02 | $mu_1$=0.716 | $mu_2$=0.283 | | | | | |
| *T-Statistic* | *17.1* | *15.6* | *14.0* | | | | | |
| *Standard Error* | *1.6.E-08* | *4.6.E-02* | *2.0.E-02* | | | | | |

$Sigma_t$ = implied forward rates in the three-month futures yield on the Euribor (average of four consecutive three-month delivery dates). $S_t$ = 10-year interest swap rate on the euro. $Y_t$ = 10-year yield to maturity on German bund. $L_t$ = 12-month interbank (Libor) rate on the euro). $R_t$ = three-month interbank (Libor) rate on the euro.

Table 4

**Government bond interest rates and market liquidity in G5 countries**

| | | Market quality measure[1] | | | | |
|---|---|---|---|---|---|---|
| | | ***$S_t$*** | ***$Y_t$*** | ***$L_t$*** | ***$R_t$*** | ***$Sigma_t$*** |
| MQM: 1993:1 | 2000:365 | 0.053 | 0.061 | 0.013 | 0.006 | 0.007 |
| MQM: 1993:1 | 1997:365 | 0.051 | 0.064 | 0.014 | 0.005 | 0.007 |
| MQM: 1998:1 | 1998:365 | 0.010<br>(0.016) | 0.008<br>(0.012) | 0.002 | 0.003 | 0.001 |
| MQM: 1999:1 | 1999:365 | 0.021<br>(0.032) | 0.019<br>(0.028) | 0.004 | 0.005 | 0.001 |
| MQM: 2000:1 | 2000:365 | 0.021<br>(0.036) | 0.026<br>(0.046) | 0.003 | 0.007 | 0.003 |
| **Factor loadings** | | **A2:** | | **A1:** | | |
| | | **W1** | **W2** | **F1** | **F2** | **F3** |
| $S_t$ | | 0.00011 | -0.000069 | 0.0056 | 0.0225 | 0.0054 |
| $Y_t$ | | 0.00005 | -0.000010 | 0.0060 | -0.0336 | 0.0019 |
| $L_t$ | | -0.00019 | 0.000025 | 0.0146 | 0.0260 | -0.0101 |
| $R_t$ | | 0.00014 | -0.000026 | -0.0221 | -0.0640 | 0.0407 |
| $Sigma_t$ | | -0.00011 | 3.13300D-07 | -0.0130 | 0.0075 | -0.0358 |

[1] In brackets: calculation with only one cointegration vector.

Table 5

**Descriptive statistics**

| **1993:1<br>2000:365** | **Germany** | **France** | **Italy** | **UK** | **US** |
|---|---|---|---|---|---|
| mean | 5.79 | 6.01 | 8.19 | 6.77 | 6.15 |
| median | 5.81 | 5.74 | 7.65 | 7.03 | 6.07 |
| standard deviation | 0.98 | 1.16 | 2.98 | 1.32 | 0.72 |
| min | 3.63 | 3.72 | 3.89 | 4.14 | 4.15 |
| max | 7.81 | 8.41 | 13.81 | 9.05 | 8.03 |
| **Correlations** | | | | | |
| Germany | 1.00 | 0.98 | 0.93 | 0.94 | 0.80 |
| France | | 1.00 | 0.95 | 0.91 | 0.75 |
| Italy | | | 1.00 | 0.91 | 0.60 |
| UK | | | | 1.00 | 0.74 |
| US | | | | | 1.00 |

Table 6

**Ten-year government bond yield: liquidity measures in the G5 countries**

| **Panel A** | **Liquidity measures** | | | | |
|---|---|---|---|---|---|
| | **Germany** | **France** | **Italy** | **UK** | **US** |
| Sample: 1993:1 - 2000:365 | | | | | |
| MQM indicator | 37.59 | 31.02 | 50.95 | 12.37 | 3.66 |
| St. dev. (transitory) | 5.25 | 8.05 | 1.75 | 0.84 | 0.22 |
| St. dev. (permanent) | 0.14 | 0.26 | 0.03 | 0.07 | 0.06 |
| Sample: 1993:1 - 2000:365 | | | | | |
| MQM indicator | 23.69 | 20.21 | 35.18 | 8.80 | 2.76 |
| St. dev. (transitory) | 4.09 | 6.27 | 1.37 | 0.65 | 0.17 |
| St. dev. (permanent) | 0.17 | 0.31 | 0.04 | 0.07 | 0.06 |
| Sample: 1993:1 - 2000:365 | | | | | |
| MQM indicator | 8.96 | 5.71 | 5.87 | 1.31 | 0.32 |
| St. dev. (transitory) | 0.45 | 0.69 | 0.15 | 0.07 | 0.02 |
| St. dev. (permanent) | 0.05 | 0.12 | 0.03 | 0.05 | 0.06 |
| Sample: 1993:1 - 2000:365 | | | | | |
| MQM indicator | 13.57 | 6.43 | 8.24 | 1.81 | 0.50 |
| St. dev. (transitory) | 0.69 | 1.06 | 0.23 | 0.11 | 0.03 |
| St. dev. (permanent) | 0.05 | 0.16 | 0.03 | 0.06 | 0.06 |
| Sample: 1993:1 - 2000:365 | | | | | |
| MQM indicator | 3.79 | 1.99 | 2.42 | 0.51 | 0.12 |
| St. dev. (transitory) | 0.16 | 0.24 | 0.05 | 0.03 | 0.01 |
| St. dev. (permanent) | 0.04 | 0.12 | 0.02 | 0.05 | 0.05 |

| **Panel B** | **A2:** | **A1:** | | | |
|---|---|---|---|---|---|
| **Factor loadings** | **W1** | **F1** | **F2** | **F3** | **F4** |
| Germany | –0.02 | 0.0212 | 0.0196 | 0.0205 | 0.0011 |
| France | 0.04 | 0.0486 | –0.0118 | 0.0077 | 0.0096 |
| Italy | –0.58 | –0.0033 | –0.0110 | 0.0135 | 0.0093 |
| UK | 0.10 | 0.0345 | 0.0244 | –0.0169 | 0.0443 |
| US | 0.18 | 0.0079 | –0.0054 | 0.0248 | 0.0495 |

| **Panel C** | **Cointegration rank test** | | |
|---|---|---|---|
| *No of cointegration vectors: r* | *Trace test* | *P-values* | *Eigenvalues* |
| HO: r=0 | 79.96 | 0.057 | 0.0177 |
| HO: r<=1 | 40.5 | 0.449 | 0.0086 |
| HO: r<=2 | 22.96 | 0.481 | 0.0072 |
| HO: r<=3 | 8.24 | 0.625 | 0.0027 |
| HO: r<=4 | 2.78 | 0.89 | 0.0014 |

Chart 1

**Euro area 10-year spread vs German bund yield: France, Italy and Spain**

(daily data; in percentage points)

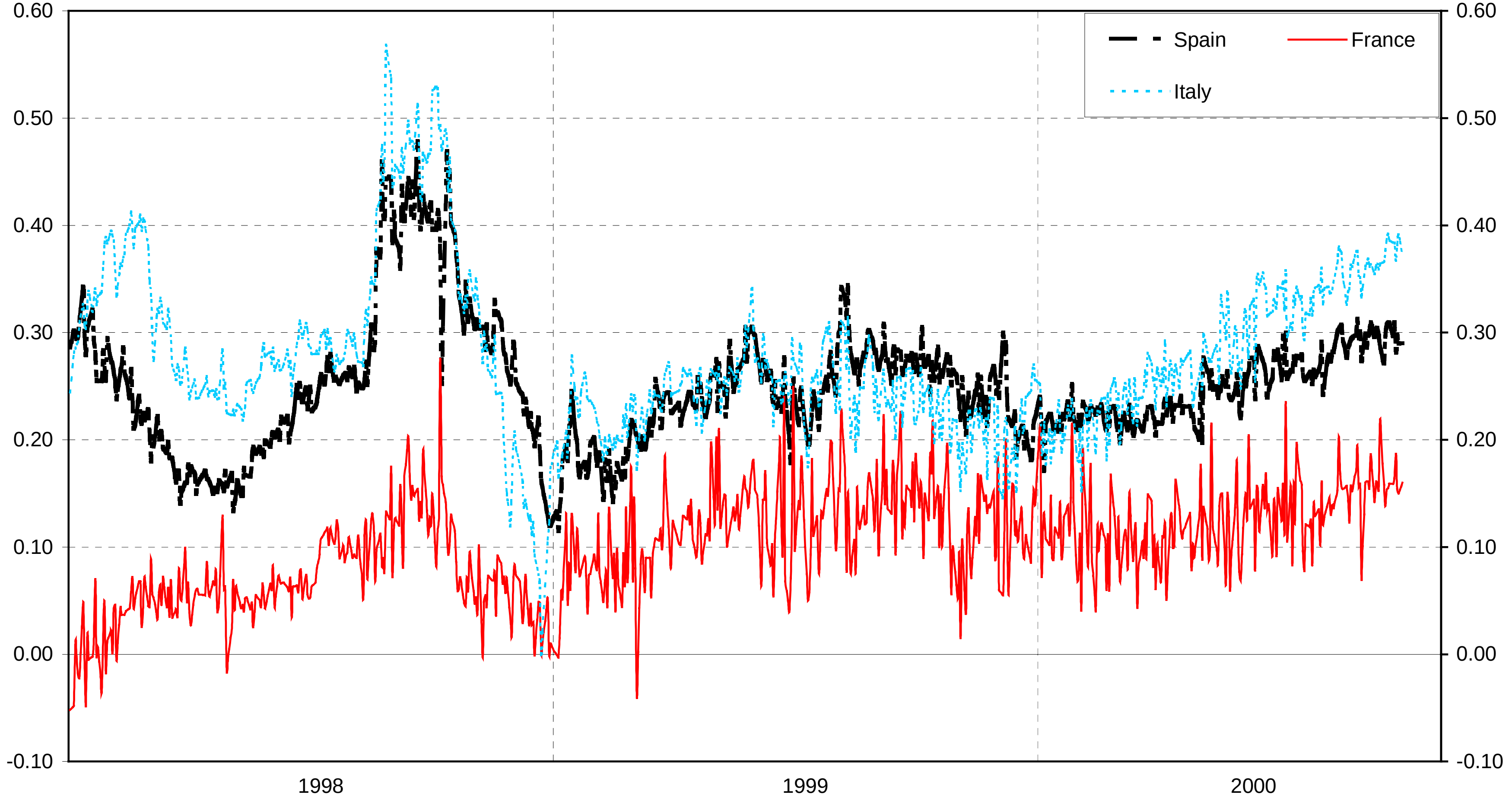


Chart 2

**Euro 10-year spread vs German bund yield and corporate**

(daily data; in percentage points)

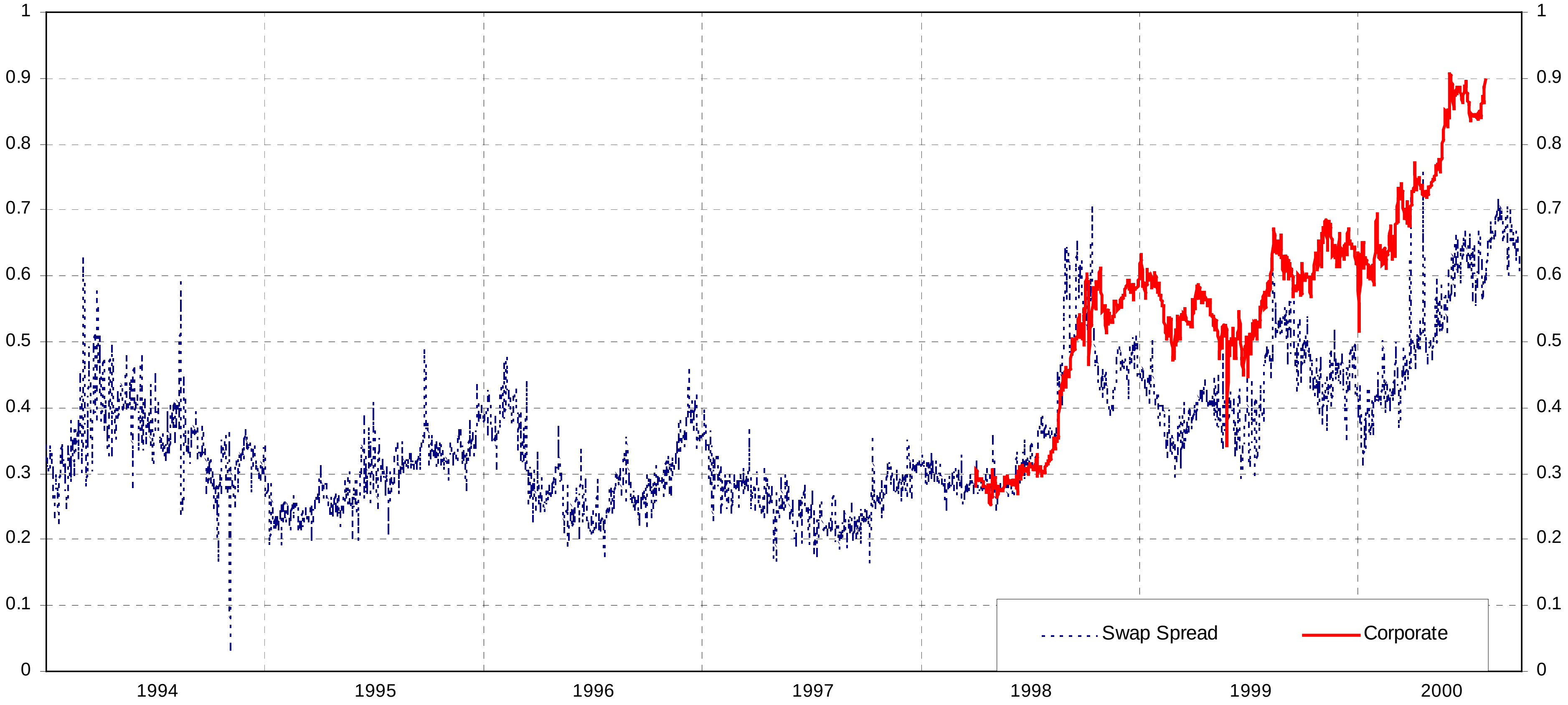


Chart 3

**Estimated GARCH volatility of 10-year swap spread vs German bund**

(daily data; in percentage points)

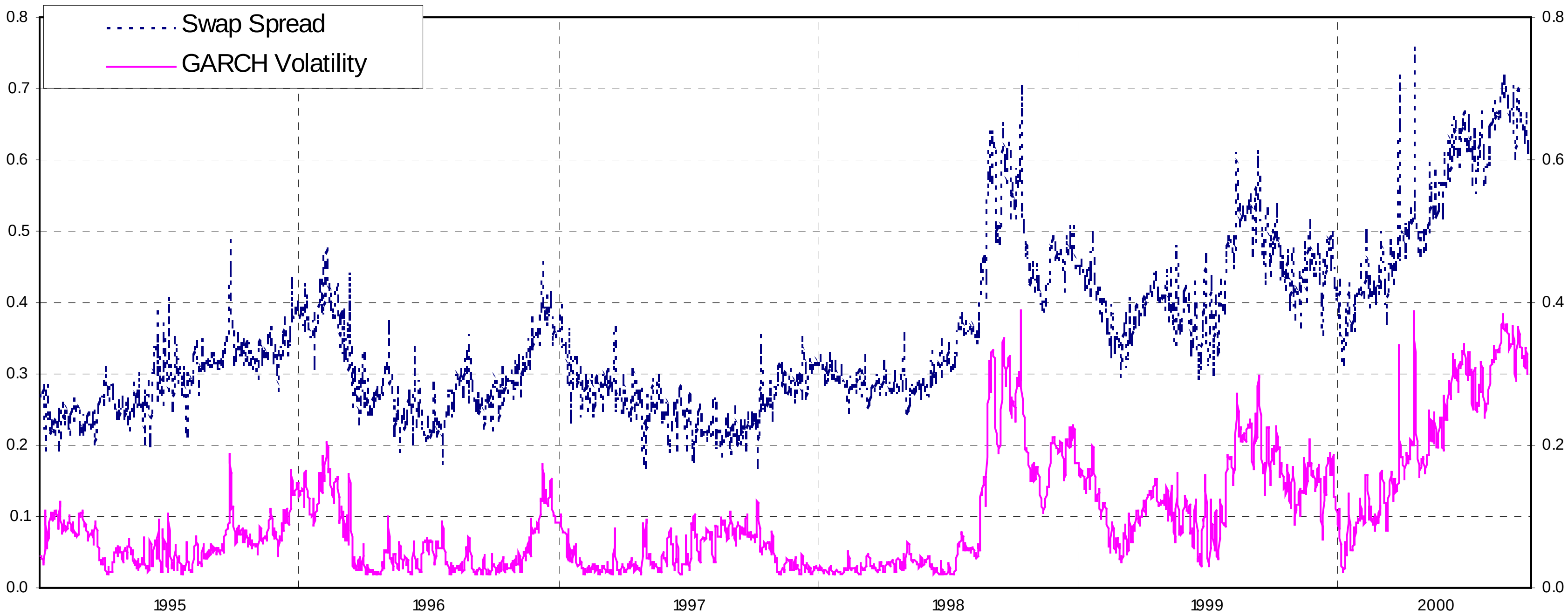


Chart 4

**Common liquidity risk measure for the G5 countries**

(daily data; in percentage points)

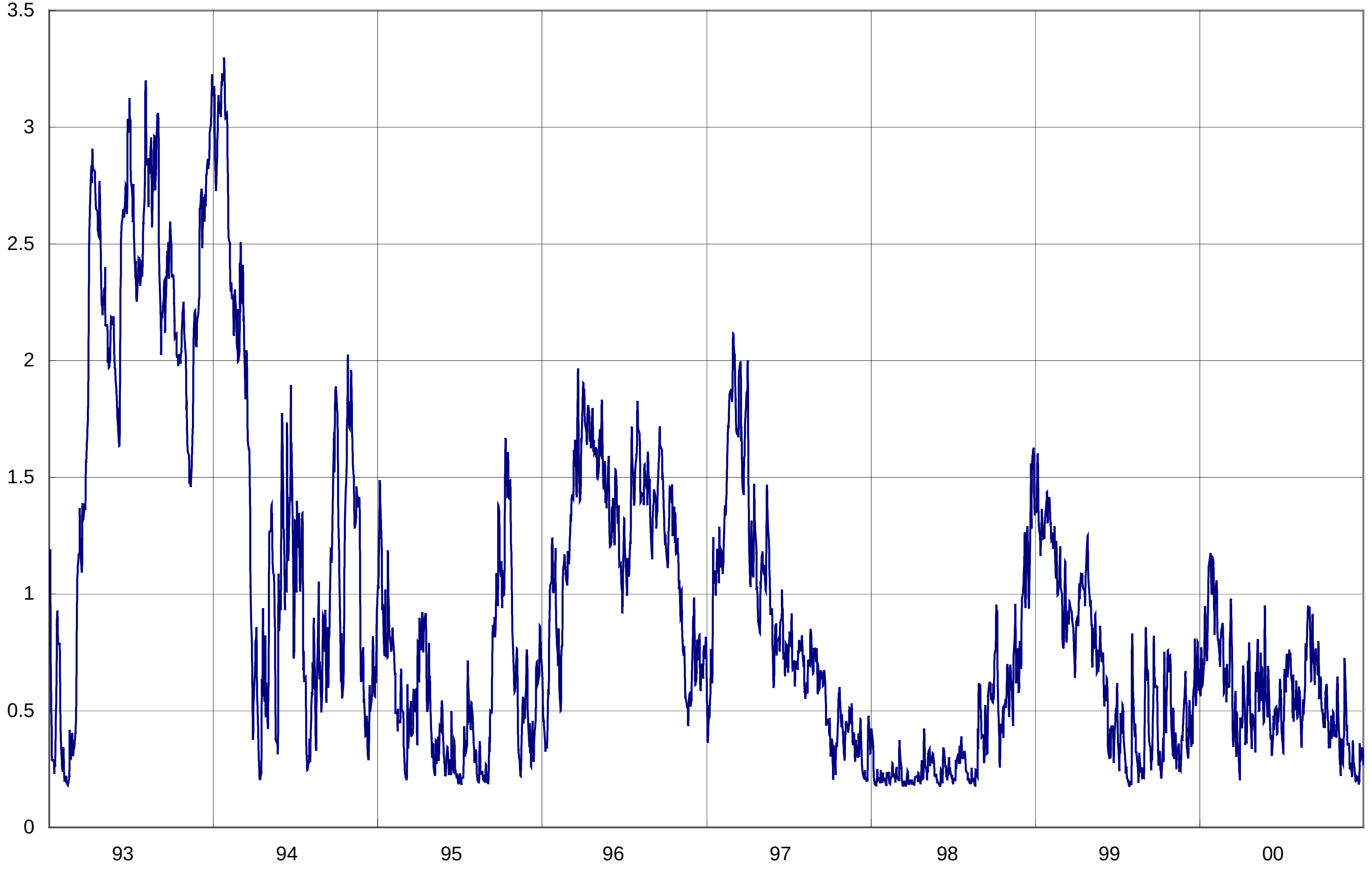


Chart 5

**US, UK and euro area (France, Germany and Italy) government bond yields: deviation from fundamental values**

(daily data; in percentage points)

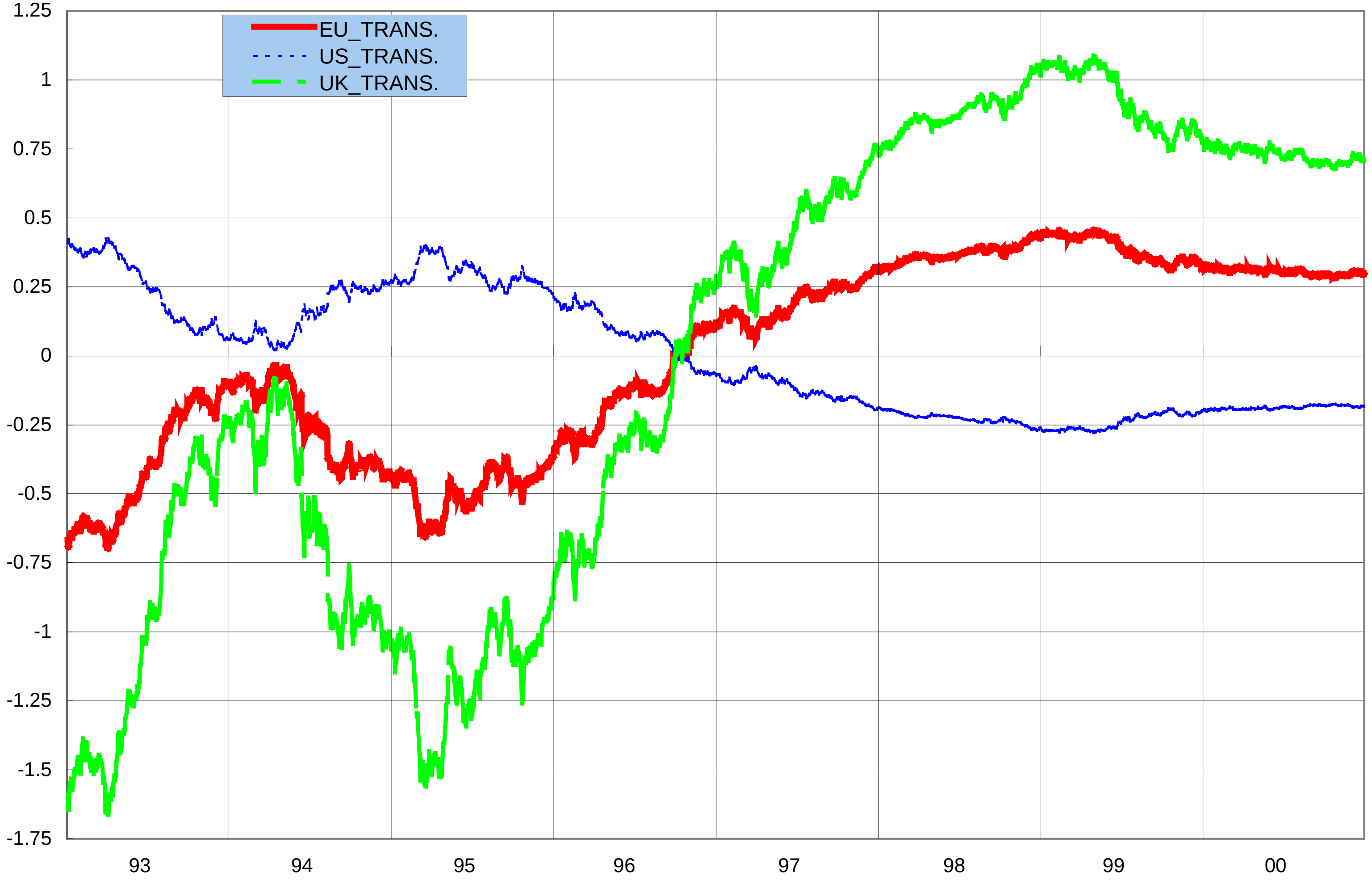
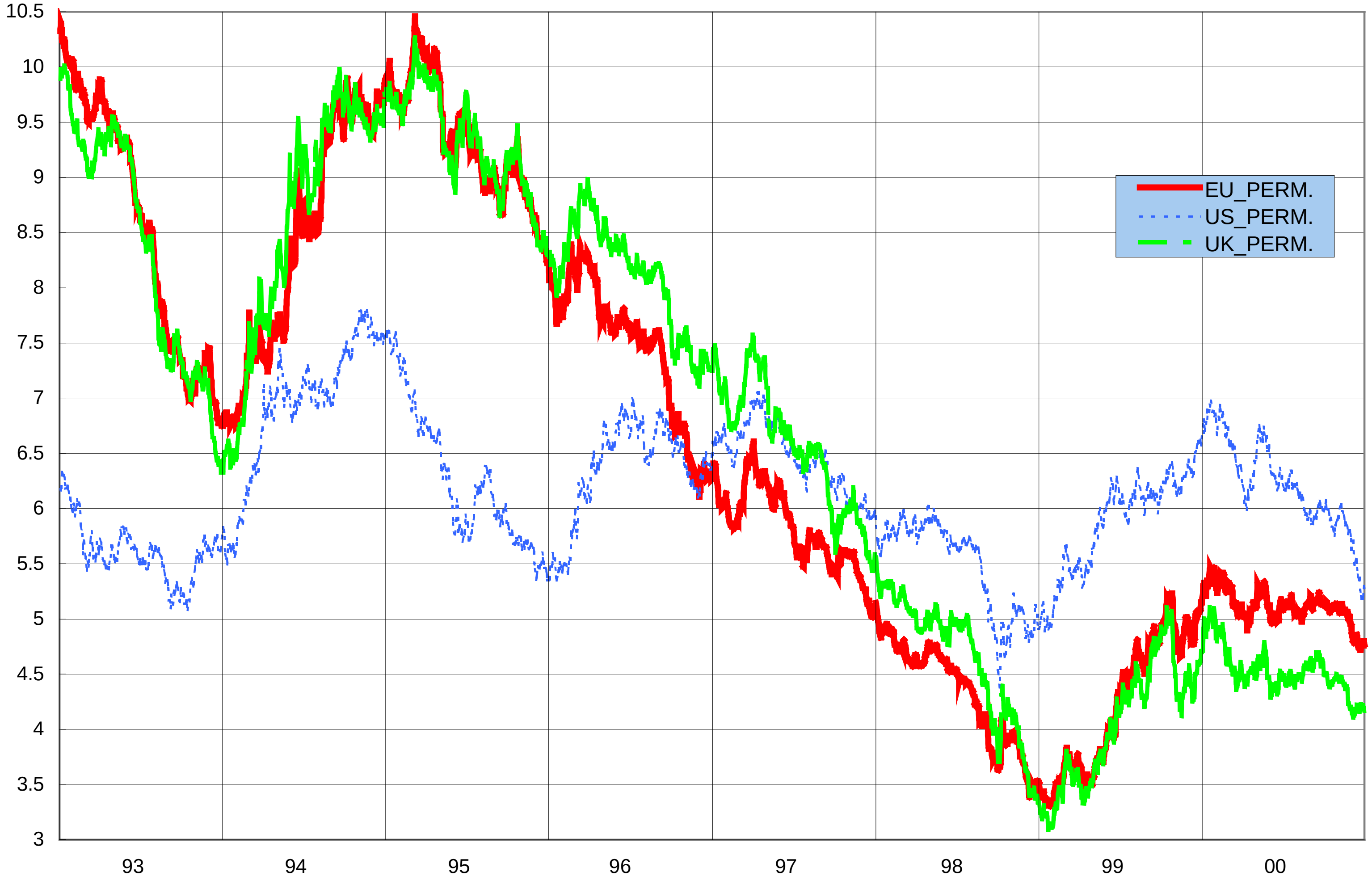


Chart 6

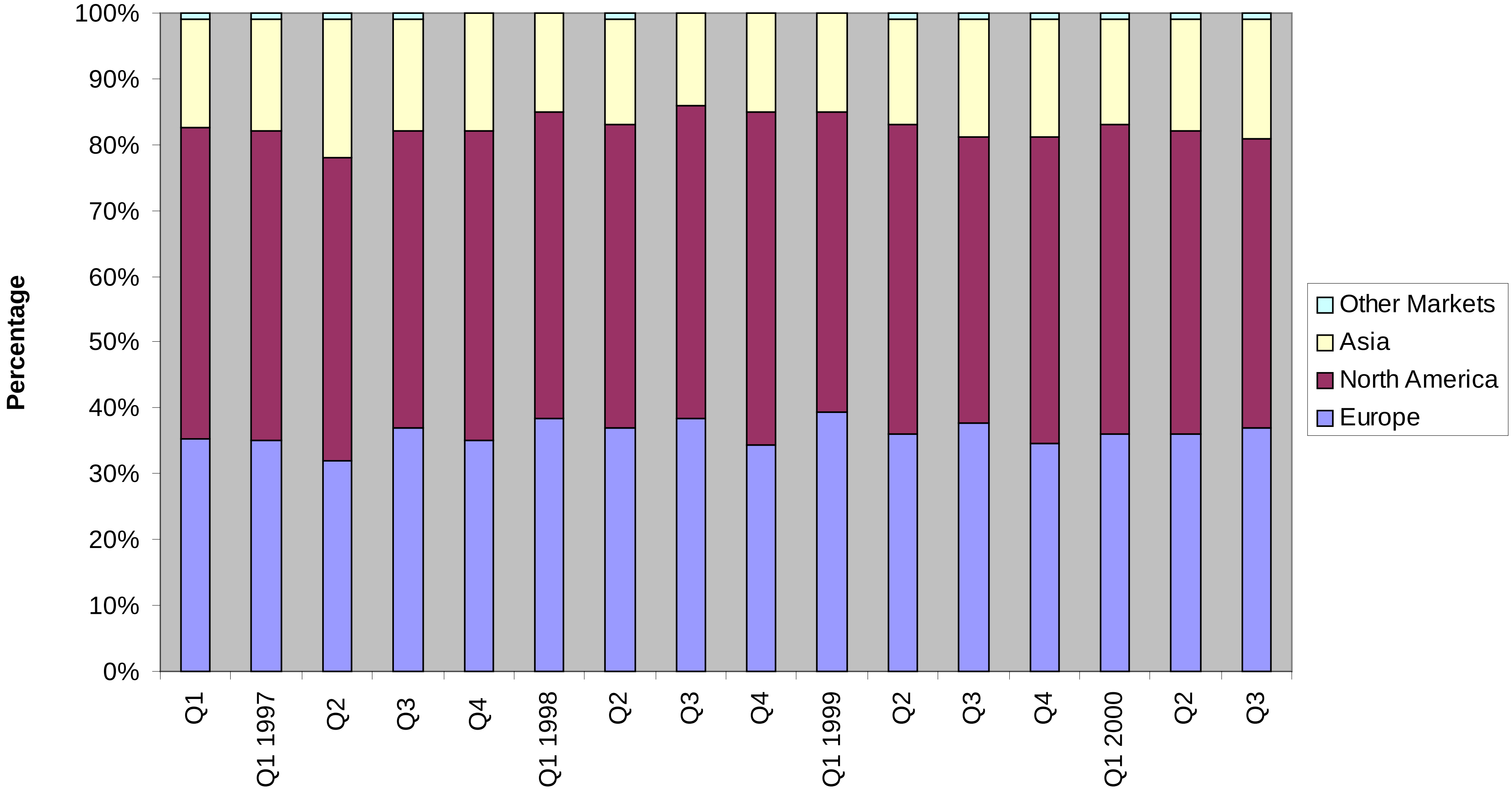
**US, UK and euro area (France, Germany and Italy) 10-year government bond yield: fundamental (long-run) values**

(daily data; in percentage points)



## Annex 1

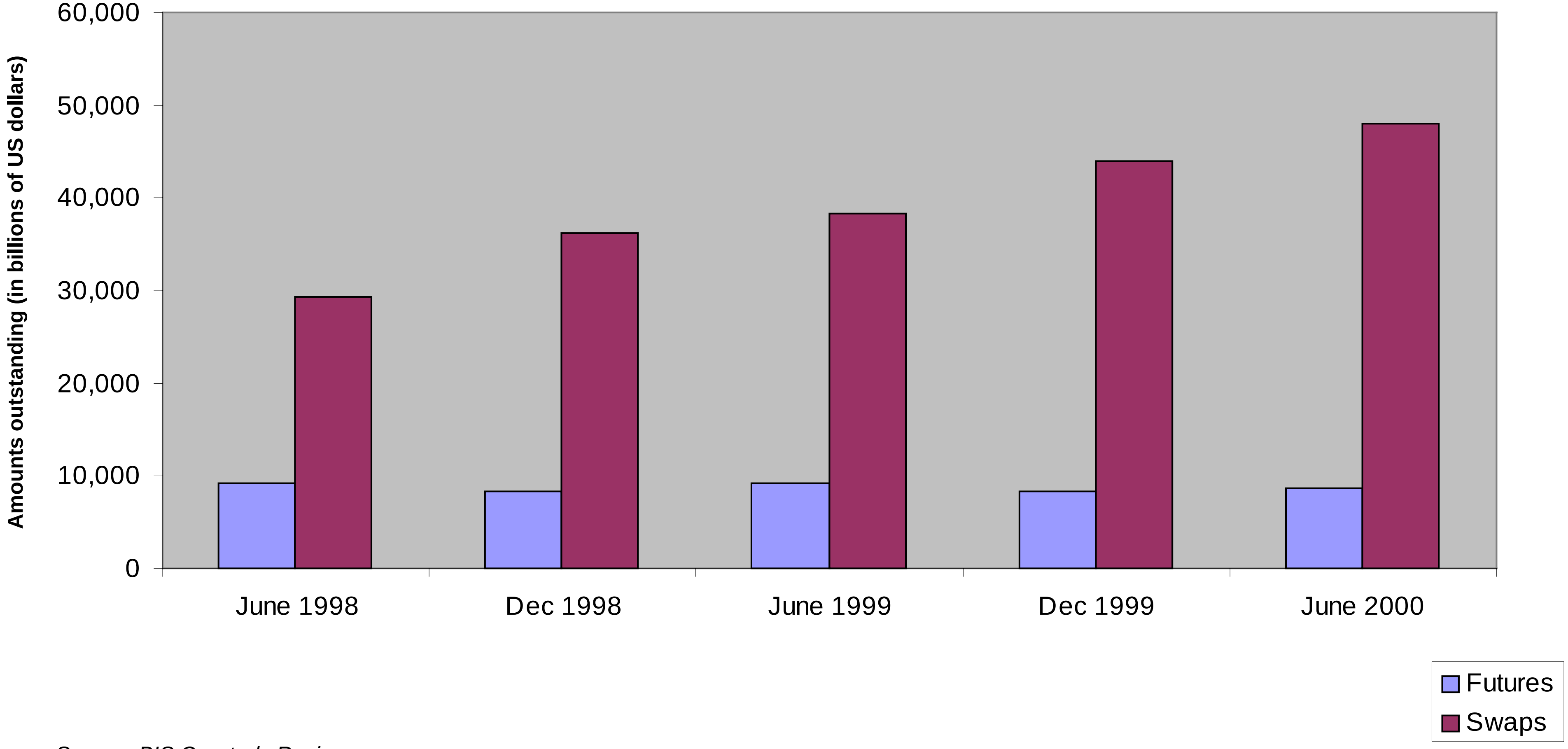
**Turnover in exchange traded interest rate derivatives by location**




Source: *BIS Quarterly Review.*

## Annex 2

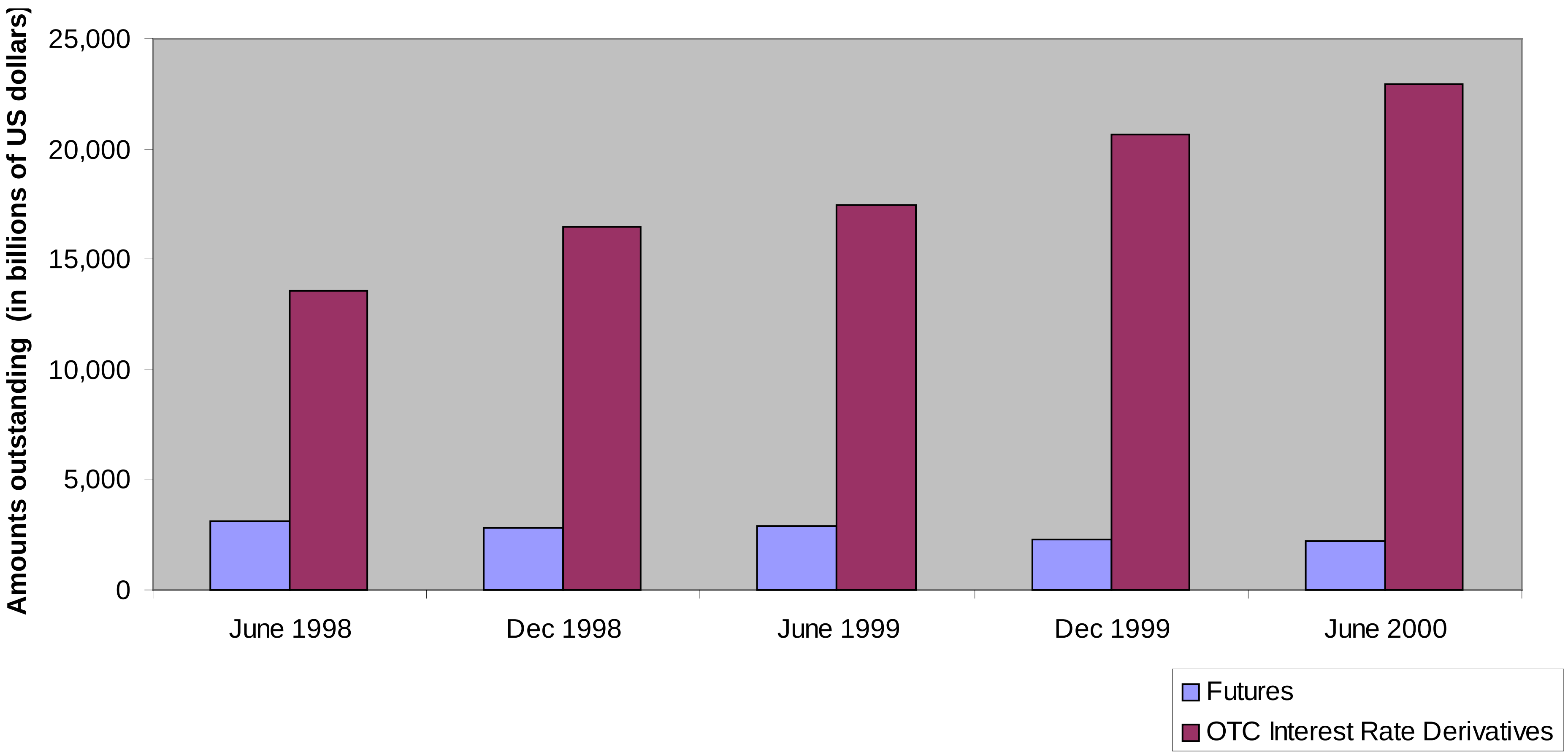
**Amounts outstanding of OTC single currency interest rate swaps and exchange traded interest rate futures in all markets (notional amounts in billions of US dollars)**




Source: *BIS Quarterly Review.*

## Annex 3

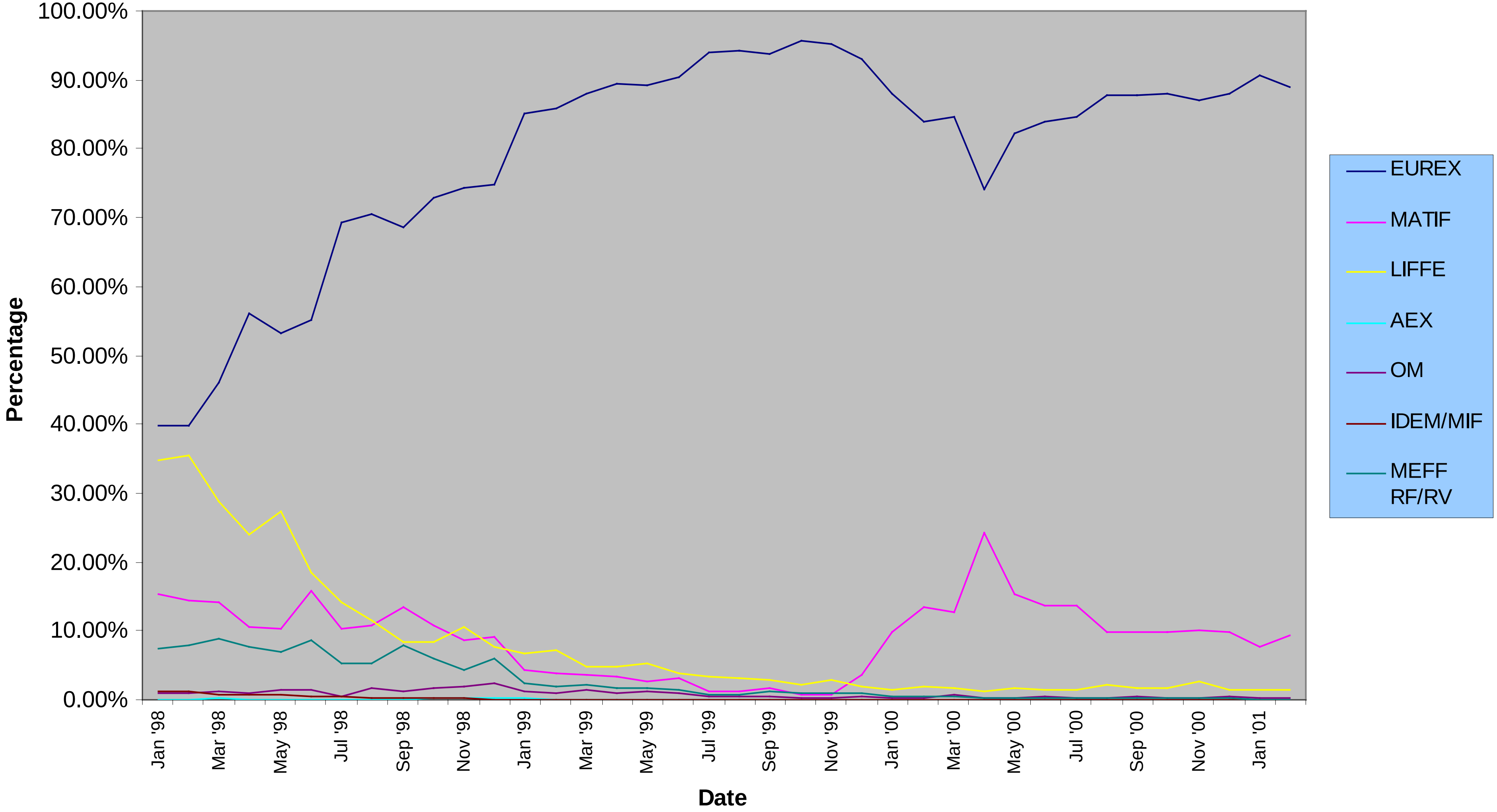
**Amounts outstanding of OTC single currency interest rate derivatives and exchange traded interest rate futures in the euro area (notional amounts in billions of US dollars)**




Source: *BIS Quarterly Review.*

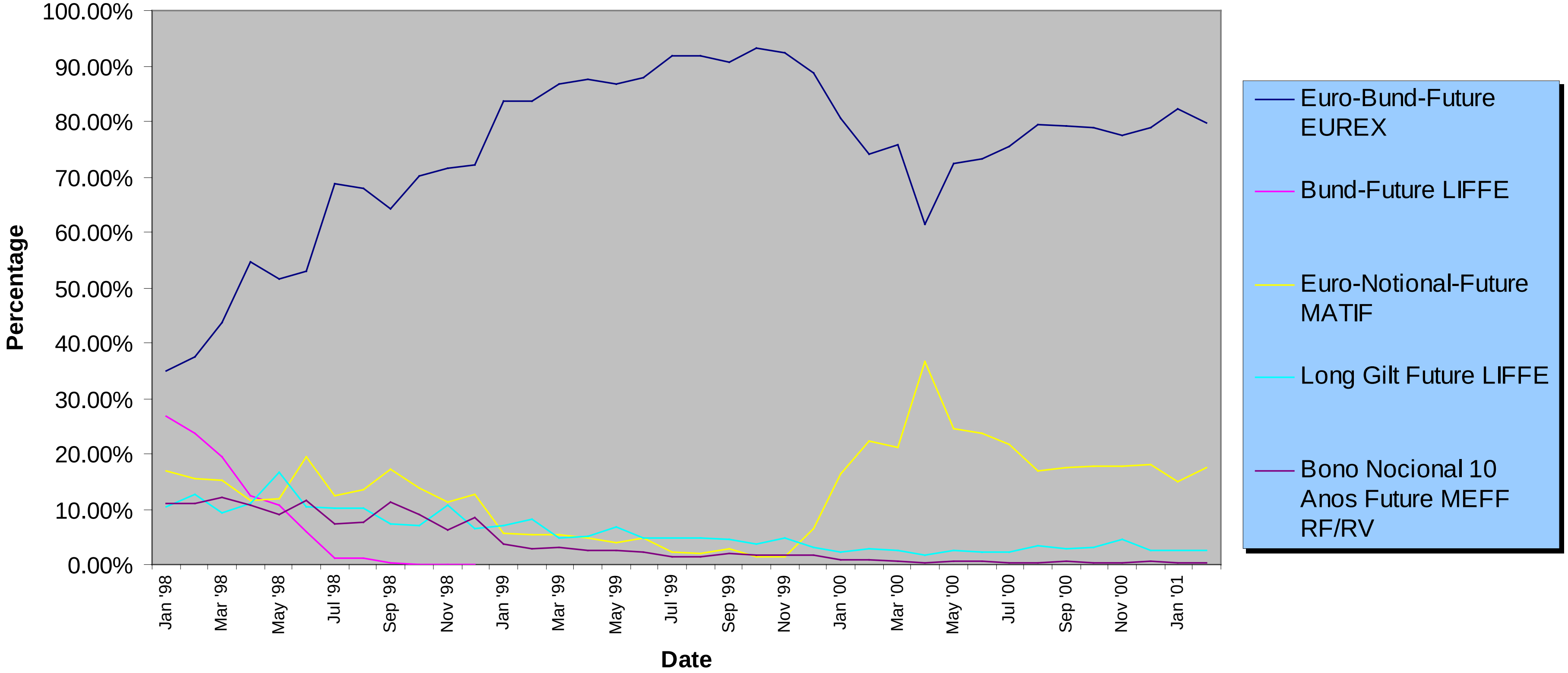
# Annex 4

## European futures exchanges - percentage of traded capital market products

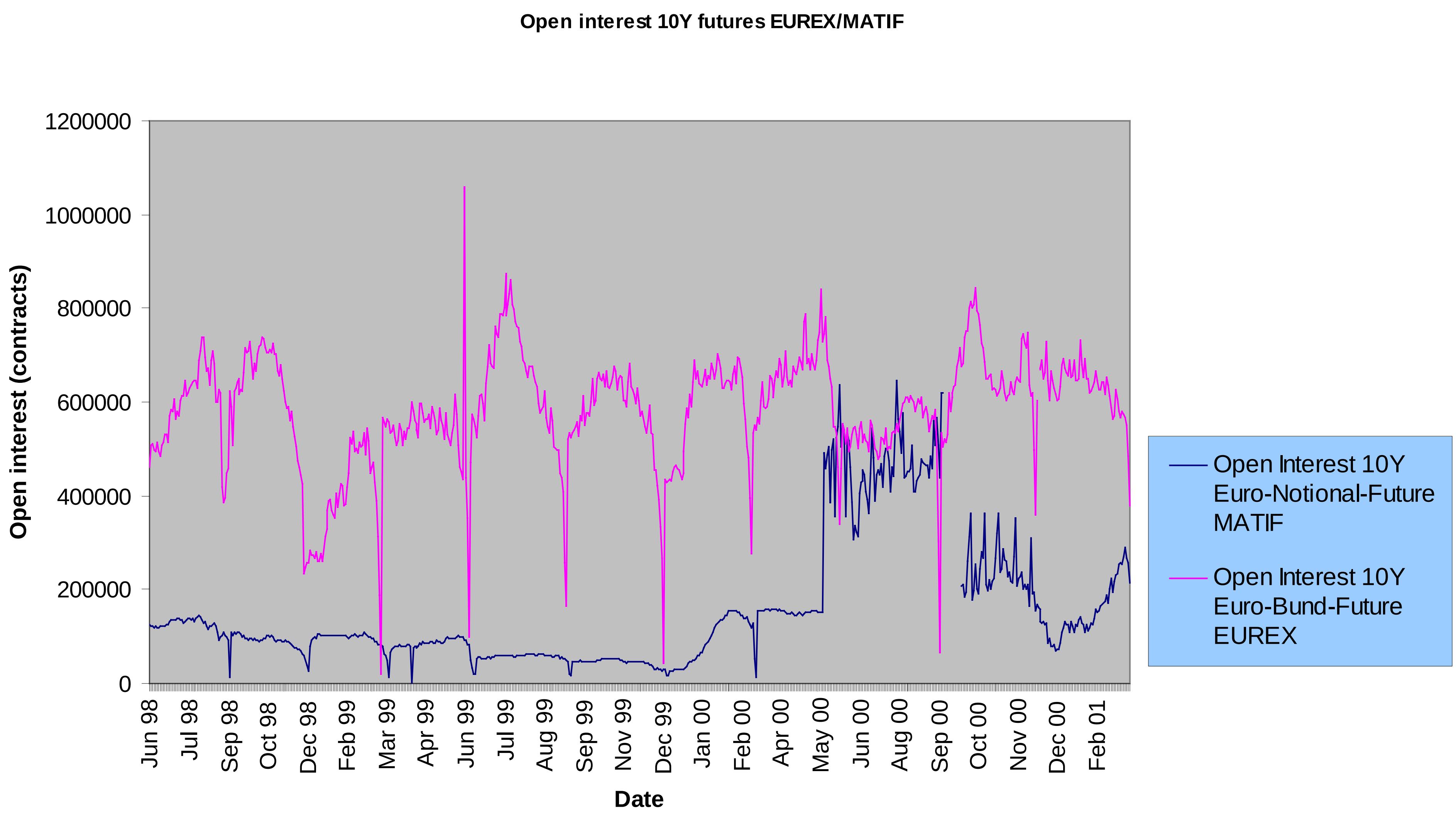


# Annex 5

**European 10Y capital market futures - traded contracts**



# Annex 6


Open interest 10Y futures EUREX/MATIF
Open interest (contracts)
1200000
1000000
800000
600000
400000
200000
0
Jun 98
Jul 98
Sep 98
Oct 98
Dec 98
Feb 99
Mar 99
Apr 99
Jun 99
Jul 99
Aug 99
Sep 99
Nov 99
Dec 99
Jan 00
Feb 00
Apr 00
May 00
Jun 00
Aug 00
Sep 00
Oct 00
Nov 00
Dec 00
Feb 01
Date
Open Interest 10Y Euro-Notional-Future MATIF
Open Interest 10Y Euro-Bund-Future EUREX

Annex 7

## Effect of a change in the notional contract coupon after the Euro Bund futures squeeze on the June 1999 delivery

| Euro Bund futures contract: June 1999 delivery | | | | | | |
|---|---|---|---|---|---|---|
| **Contracts delivery date:** | **10.06.1999** | | | | | |
| Bond No | 113505 | 113507 | 113509 | 113510 | 113511 | |
| Size (EUR millions) | 15,339 | 8,692 | 13,805 | 14,000 | 11,000 | |
| Coupon | 5.25 | 4.75 | 4.125 | 3.75 | 4.00 | |
| Maturity | 04.01.2008 | 04.07.2008 | 04.07.2008 | 04.01.2009 | 04.07.2009 | |
| Yield (ISMA in %) | 6 | 6 | 6 | 6 | 6 | |
| Duration | 6.92 | 7.15 | 7.31 | 7.92 | 7.98 | |
| Modified duration | 6.52 | 6.75 | 6.90 | 7.47 | 7.53 | Range: 1,01 |
| Price | 95.05 | 91.44 | 87.17 | 83.95 | 85.15 | |
| Conversion factor (6%) | 0.95049 | 0.914424 | 0.871737 | 0.839458 | 0.851507 | |
| Converted price | ***100.00*** | ***100.00*** | ***100.00*** | ***100.00*** | ***100.00*** | Range: 0,00 |
| **Scenario1: Market yield level stays below the level of the notional contract coupon** | | | | | | |
| Yield (ISMA in %) | 4 | 4 | 4 | 4 | 4 | |
| Duration | 7.05 | 7.32 | 7.47 | 8.07 | 8.18 | |
| Modified duration | 6.79 | 7.03 | 7.18 | 7.76 | 7.86 | Range: 1,09 |
| Price | 108.90 | 105.61 | 100.93 | 98.03 | 99.96 | |
| Converted price | ***114.57*** | 115.49 | 115.78 | 116.77 | 117.39 | Range: 2,82 |
| **Scenario 2: Relative yield change required to change the CTD bond** | | | | | | |
| Yield (ISMA in %) | ***3.88*** | 4 | 4 | 4 | 4 | |
| Duration | 7.05 | 7.32 | 7.47 | 8.07 | 8.18 | Range: 1,09 |
| Modified duration | 6.79 | 7.03 | 7.18 | 7.76 | 7.86 | |
| Price | 109.80 | 105.61 | 100.93 | 98.03 | 99.96 | |
| Converted price | 115.52 | ***115.49*** | 115.78 | 116.77 | 117.39 | Range: 1,90 |
| **Scenario 3: The notional contract coupon is lowered to 4%, which was the market yield level on June 1999 delivery** | | | | | | |
| Conversion factor (4%) | 1.088954 | 1.056048 | 1.009335 | 0.98027 | 0.999605 | |
| Yield (ISMA in %) | 4 | 4 | 4 | 4 | 4 | |
| Duration | 7.04 | 7.32 | 7.47 | 8.07 | 8.18 | |
| Modified duration | 6.77 | 7.03 | 7.18 | 7.76 | 7.86 | Range: 1,09 |
| Price | 108.90 | 105.61 | 100.93 | 98.03 | 99.96 | |
| Converted price | ***100.00*** | ***100.00*** | ***100.00*** | ***100.00*** | ***100.00*** | Range: 0,00 |
| **Scenario 4: Market yield level stays above the level of the adjusted notional contract coupon (4%)** | | | | | | |
| Yield (ISMA in %) | 5 | 5 | 5 | 5 | 5 | |
| Duration | 6.98 | 7.23 | 7.39 | 8.00 | 8.08 | |
| Modified duration | 6.65 | 6.89 | 7.04 | 7.62 | 7.69 | Range: 0,91 |
| Price | 101.68 | 98.21 | 93.74 | 90.65 | 92.19 | |
| Converted price | 93.37 | 92.99 | 92.88 | 92.48 | ***92.23*** | Range: 1,14 |

The respective CTD bond is highlighted in each case.
The conversion factor for each deliverable bond is calculated according to the EUREX conversion factor formula; see EUREX circular 106/99 of 20 October 1999.

Annex 8.1

## 10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): September 1998 delivery

**10Y Euro Bund futures contract September 1998 (09.06.98-08.09.98; delivery: 10.09.98)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| 113503 | 25.04.1997 | 15.339 | 6 | 04.07.2007 | 0.999674 | 4,412.4 (29% of outst. amount) | 738,281 (12.08.98) | 63 | 6.85 | 4.275 |
| 113505 | 09.01.1998 | 15.339 | 5.25 | 04.01.2008 | 0.947629 | 25.4 (0.16% of outst. amount) | | 0 | 7.12 | 4.266 |
| 113507 | 10.07.1998 | 8.692 | 4.75 | 04.07.2008 | 0.909448 | | | 0 | 7.71 | 4.252 |
| Total deliv. volume | | 39.370 | | | | | | | | |

Nominal contract value: DEM 250,000

**10Y Euro Notional futures contract September 1998 (16.06.98-14.09.98; delivery: 18.09.98)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| FR0000570665 | 25.10.1997 | 16,245 | 8.5 | 25.10.2008 | 1.227773 | na | 143,642 (10.08.98) | 63 | 6.91 | 4.212 |
| FR0000570574 | 25.04.1997 | 16,938 | 5.5 | 25.04.2007 | 0.99965 | | | 0 | 6.75 | 4.111 |
| FR0000570590 | 25.10.1997 | 15,327 | 5.5 | 25.10.2007 | 0.999855 | | | 0 | 6.89 | 4.166 |
| FR0000570632 | 25.04.1998 | 16,408 | 5.25 | 25.04.2008 | 0.981386 | | | 0 | 7.41 | 4.201 |
| Total deliv. volume | | 64,918 | | | | | | | | |

Nominal contract value: FRF 500,000

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

**Correlations (daily/weekly)**

| | Germany | | France | | Italy |
|---|---|---|---|---|---|
| | Benchmark bond | CTD bond | Benchmark bond | CTD bond | Benchmark bond |
| | 113507 | 113503 | 570632 | 570665 | |
| Bund future | 0.847/0.805 | 0.880/0.948 | 0.898/0.886 | 0.889/0.884 | 0.593/0.379 |
| Euro Notional future | 0.879/0.920 | 0.895/0.972 | 0.919/0.960 | 0.920/0.955 | 0.690/0.621 |
| DEM swaps | 0.405/0.444 | 0.403/0.242 | - | - | - |
| FRF swaps | - | - | 0.665/0.608 | 0.676/0.606 | - |
| ITL swaps | - | - | - | - | 0.613/0.956 |

Daily period: 08.07.98-14.09.98. Weekly period: 17.07.98-11.09.98. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

## Annex 8.2

# 10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): December 1998 delivery

**10Y Euro Bund futures contract December 1998 (09.09.98-08.12.98; delivery: 10.12.98)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| 113503 | 25.04.1997 | 15.339 | 6 | 04.07.2007 | 0.999563 | 3,025.8 (19.7% of outst. amount) | 767,452 (09.10.98) | 63 | 6.66 | 3.895 |
| 113505 | 09.01.1998 | 15.339 | 5.25 | 04.01.2008 | 0.948987 | | | 0 | 6.94 | 3.854 |
| 113507 | 10.07.1998 | 8.692 | 4.75 | 04.07.2008 | 0.911092 | 3.19 (0.036% of outst. amount) | | 0 | 7.53 | 3.87 |
| 113509 | 30.10.1998 | 13,805 | 4.125 | 04.07.2008 | 0.866857 | | | 0 | 7.68 | 3.888 |
| Total deliv. volume | | 53,175 | | | | | | | | |

Nominal contract value: DEM 250,000

**10Y Euro Notional futures contract December 1998 (15.09.98-14.12.98; delivery: 18.12.98)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| FR0000570665 | 25.10.1997 | 16,245 | 8.5 | 25.10.2008 | 1.223459 | 1,123.5 (6.92% of outst. amount) | 109,367 (18.09.98) | 64 | 7.16 | 3.862 |
| FR0000570590 | 25.10.1997 | 15,327 | 5.5 | 25.10.2007 | 0.999824 | | | 0 | 7.03 | 3.824 |
| FR0000570632 | 25.04.1998 | 24,703 | 5.25 | 25.04.2008 | 0.981761 | 50.5 (0.2% of outst. amount) | | 0 | 7.22 | 3.863 |
| Total deliv. volume | | 56,275 | | | | | | | | |

Nominal contract value: FRF 500,000

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

**Correlations (daily/weekly)**

| | Germany | | France | | Italy |
|---|---|---|---|---|---|
| | Benchmark bond | CTD bond | Benchmark bond | CTD bond | Benchmark bond |
| | 113509 | 113503 | 571432 | 570665 | |
| Bund future | 0.821/0.917 | 0.854/0.952 | 0.849/0.961 | 0.849/0.966 | 0.600/0.871 |
| Euro Notional future | 0.674/0.921 | 0.722/0.922 | 0.799/0.923 | 0.772/0.920 | 0.534/0.709 |
| DEM swaps | 0.766/0.868 | 0.756/0.796 | - | - | - |
| FRF swaps | - | - | 0.792/0.951 | 0.820/0.963 | - |
| ITL swaps | - | - | - | - | 0.638/0.819 |

Daily period: 28.10.98-14.12.98. Weekly period: 06.11.98-11.12.98. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

## Annex 8.3

## 10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): March 1999 delivery

**10Y Euro Bund futures contract March 1999 (09.12.98-08.03.99; delivery: 10.03.99)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| 113505 | 09.01.1998 | 15.339 | 5.25 | 04.01.2008 | 0.949788 | 3,052.1 (19.9% of outst. amount) | 591,424 (23.02.99) | 58 | 7.01 | 4.089 |
| 113507 | 10.07.1998 | 8.692 | 4.75 | 04.07.2008 | 0.912935 | | | 0 | 7.26 | 4.077 |
| 113509 | 30.10.1998 | 13,805 | 4.125 | 04.07.2008 | 0.869567 | | | 0 | 7.41 | 4.094 |
| 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 0.837267 | 11 (0.078% of outst. amount) | | 0 | 7.99 | 4.054 |
| Total deliv. volume | | 37,836 | | | | | | | | |

| Delivered vol.: | Bund future: 19,385 | Contracts: 2,477.8 Mio Euro | Nominal contract value: DEM 250,000 |
|---|---|---|---|
| | Euro ^Bund future: 5,743 | Contracts: 574.3 Mio Euro | Nominal contract value: Euro 100,000 |

**10Y Euro Notional futures contract March 1999 (15.12.98-15.03.99; delivery: 19.03.99)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| FR0000570665 | 25.10.1997 | 16,245 | 8.5 | 25.10.2008 | 1.218868 | 1,125.7 (6.93% of outst. amount) | 107,576 (19.02.99) | 24 | 6.89 | 4.051 |
| FR0000570590 | 25.10.1997 | 15,327 | 5.5 | 25.10.2007 | 0.999651 | | | 38 | 6.77 | 4.000 |
| FR0000570632 | 25.04.1998 | 24,703 | 5.25 | 25.04.2008 | 0.982317 | | | 0 | 6.95 | 4.054 |
| FR0000571432 | 25.04.1998 | 19,291 | 4 | 25.04.2009 | 0.885896 | | | | 8.09 | 4.116 |
| Total deliv. volume | | 75,566 | | | | | | | | |

Nominal contract value: Euro 100,000

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

**Correlations (daily/weekly)**

| | Germany | | France | | Italy |
|---|---|---|---|---|---|
| | Benchmark bond | CTD bond | Benchmark bond | CTD bond | Benchmark bond |
| | 113510 | 113505 | 571432 | 570665 | |
| Bund future | 0.850/0.777 | 0.865/0.837 | 0.862/0.825 | 0.851/0.845 | 0.824/0.618 |
| Euro Notional future | 0.951/0.955 | 0.958/0.966 | 0.966/0.961 | 0.964/0.978 | 0.910/0.878 |
| Euro swaps | 0.908/0.958 | 0.915/0.956 | 0.907/0.974 | 0.899/0.963 | 0.923/0.970 |

Daily period: 06.01.99-05.03.99. Weekly period: 15.01.99-05.03.99. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.4

## 10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): June 1999 delivery

**10Y Euro Bund futures contract June 1999 (09.03.99-08.06.99; delivery 10.06.99)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| 113505 | 09.01.1998 | 15.339 | 5.25 | 04.01.2008 | 0.950792 | 5,441.3 (35.5% of outst. amount) | 1,057,000 (01.06.99) | 59 | 6.75 | 4.226 |
| 113507 | 10.07.1998 | 8.692 | 4.75 | 04.07.2008 | 0.914979 | | | 0 | 7 | 4.23 |
| 113509 | 30.10.1998 | 13,805 | 4.125 | 04.07.2008 | 0.872468 | | | 0 | 7.14 | 4.246 |
| 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 0.840315 | | | 0 | 7.73 | 4.225 |
| 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 0.852798 | | | | 8.06 | 4.228 |
| Total deliv. volume | | 62,836 | | | | | | | | |

**10Y Euro Notional futures contract June 1999 (16.03.99-14.06.99; delivery: 18.06.99)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| Bund 113505 | 09.01.1998 | 15,339 | 5.25 | 04.01.2008 | 1.127267 | | 101,309 (26.05.99) | 0 | 6.71 | 4.355 |
| OAT FR0000570632 | 25.04.1998 | 25,292 | 5.25 | 25.04.2008 | 1.131264 | | | 6 | 7 | 4.375 |
| Bund 113507 | 10.07.1998 | 8,692 | 4.75 | 04.07.2008 | 1.095524 | | | 0 | 6.96 | 4.358 |
| OAT FR0000570665 | 25.10.1997 | 16,245 | 8.5 | 25.10.2008 | 1.393006 | | | 0 | 6.6 | 4.38 |
| Bund 113509 | 30.10.1998 | 13,805 | 4.125 | 04.07.2008 | 1.047747 | | | 5 | 7.11 | 4.367 |
| Bund 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 1.019853 | | | 0 | 7.7 | 4.329 |
| OAT FR0000571432 | 25.04.1998 | 22,522 | 4.000 | 25.04.2009 | 1.041014 | 1,251.1 (5.56% of outst. amount) | | 38 | 7.9 | 4.454 |
| Bund 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 1.041412 | | | 15 | 8.03 | 4.312 |
| Total deliv. volume | | 126,895 | | | | | | | | |

Basket of deliverable bonds changed by MATIF on June 1999 delivery: dual issuer basket with French and German issues. In addition, notional coupon lowered from 5.5% to 3.5%.

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

**Correlations (daily/weekly)**

| | Germany | | France | | Italy |
|---|---|---|---|---|---|
| | Benchmark bond | CTD bond | Benchmark bond | CTD bond | Benchmark bond |
| | 113511 | 113505 | 571432 | 571432 | |
| Euro Bund future | 0.791/0.929 | 0.817/0.968 | 0.808/0.933 | 0.808/0.933 | 0.715/0.928 |
| Euro Notional future | 0.910/0.918 | 0.908/0.944 | 0.938/0.943 | 0.938/0.943 | 0.916/0.937 |
| Euro swaps | 0.715/0.866 | 0.720/0.884 | 0.732/0.897 | 0.732/0.897 | 0.667/0.897 |

Daily period: 23.03.99-14.06.99. Weekly period: 02.04.99-11.06.99. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

## Annex 8.5

## 10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): September 1999 delivery

**10Y Euro Bund futures contract September 1999 (09.06.99-08.09.99; delivery: 10.09.99)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| 113507 | 10.07.1998 | 8,692 | 4.75 | 04.07.2008 | 0.916530 | 1,050.3 (12.1% of outst. amount) | 872,127 (13.07.99) | 60 | 6.97 | 5.009 |
| 113509 | 30.10.1998 | 13,805 | 4.125 | 04.07.2008 | 0.874958 | 20 (0.14% of outst. amount) | | 4 | 7.1 | 5.016 |
| 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 0.843546 | | | 0 | 7.37 | 5.005 |
| 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 0.855312 | | | 0 | 7.7 | 4.992 |
| 113512 | 09.07.1999 | 20,000 | 4.500 | 04.07.2009 | 0.891403 | | | 0 | 7.65 | 5.008 |
| Total deliv. volume | | 67,497 | | | | | | | | |

**10Y Euro Notional futures contract September 1999 (15.06.99-13.09.99; delivery: 17.09.99)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| OAT FR0000570632 | 25.04.1998 | 25,292 | 5.25 | 25.04.2008 | 1.127991 | | 63,305 (03.08.99) | 0 | 6.67 | 5.129 |
| Bund 113507 | 10.07.1998 | 8,692 | 4.75 | 04.07.2008 | 1.093188 | | | 0 | 6.95 | 5.115 |
| OAT FR0000570665 | 25.10.1997 | 16,245 | 8.5 | 25.10.2008 | 1.384281 | | | 0 | 6.24 | 5.112 |
| Bund 113509 | 30.10.1998 | 13,805 | 4.125 | 04.07.2008 | 1.046547 | | | 0 | 7.08 | 5.118 |
| Bund 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 1.019432 | | | 0 | 7.35 | 5.109 |
| OAT FR0000571432 | 25.04.1998 | 22,522 | 4.000 | 25.04.2009 | 1.040059 | | | 0 | 7.56 | 5.189 |
| Bund 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 1.040488 | | | 0 | 7.68 | 5.089 |
| Bund 113512 | 09.07.1999 | 20,000 | 4.500 | 04.07.2009 | 1.081669 | | | 0 | 7.63 | 5.109 |
| OAT FR0000186199 | 25.10.1999 | 13,697 | 4 | 25.10.2009 | 1.041905 | 1,685.6 (12.3% of outst. amount) | | 65 | 7.69 | 5.24 |
| Total deliv. volume | | 145,253 | | | | | | | | |

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

**Correlations (daily/weekly)**

| | Germany | | France | | Italy |
|---|---|---|---|---|---|
| | Benchmark bond | CTD bond | Benchmark bond | CTD bond | Benchmark bond |
| | 113512 | 113507 | 186199 | 186199 | |
| Euro Bund future | 0.847/0.932 | 0.842/0.947 | 0.867/0.929 | 0.867/0.929 | 0.656/0.924 |
| Euro Notional future | 0.936/0.986 | 0.940/0.993 | 0.944/0.987 | 0.944/0.987 | 0.803/0.984 |
| Euro swaps | 0.834/0.943 | 0.827/0.936 | 0.863/0.950 | 0.863/0.950 | 0.627/0.942 |

Daily period: 07.07.99-13.09.99. Weekly period: 16.07.99-10.09.99. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.6

## 10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): December 1999 delivery

**10Y Euro Bund futures contract December 1999 (09.09.99-08.12.99; delivery: 10.12.99)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| 113507 | 10.07.1998 | 8.692 | 4.75 | 04.07.2008 | 0.917801 | 748.2 (8.6% of outst. amount) | 682,910 (05.11.99) | 61 | 6.73 | 5.039 |
| 113509 | 30.10.1998 | 13,805 | 4.125 | 04.07.2008 | 0.876915 | 0.2 (0.001% of outst. amount) | | 2 | 6.86 | 5.042 |
| 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 0.846008 | | | 0 | 7.13 | 5.034 |
| 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 0.856929 | | | 0 | 7.46 | 5.033 |
| 113512 | 09.07.1999 | 20,000 | 4.500 | 04.07.2009 | 0.892856 | | | 0 | 7.4 | 5.07 |
| 113513 | 22.10.1999 | 11,000 | 5.375 | 04.01.2010 | 0.953223 | | | | 7.62 | 5.063 |
| Total deliv. volume | | 78,497 | | | | | | | | |

**10Y Euro Notional futures contract December 1999 (14.09.99-13.12.99; delivery: 17.12.99)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| Bund 113507 | 10.07.1998 | 8,692 | 4.75 | 04.07.2008 | 1.090849 | | 53,975 (26.10.99) | 0 | 6.73 | 4.989 |
| OAT FR0000570665 | 25.10.1997 | 16,245 | 8.5 | 25.10.2008 | 1.375275 | | | 0 | 6.45 | 4.946 |
| Bund 113509 | 30.10.1998 | 13,805 | 4.125 | 04.07.2008 | 1.045350 | | | 0 | 6.86 | 4.988 |
| Bund 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 1.019088 | | | 0 | 7.13 | 4.982 |
| OAT FR0000571432 | 25.04.1998 | 22,522 | 4.000 | 25.04.2009 | 1.039181 | | | 0 | 7.34 | 5.066 |
| Bund 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 1.039643 | | | 0 | 7.46 | 4.983 |
| Bund 113512 | 09.07.1999 | 20,000 | 4.500 | 04.07.2009 | 1.079848 | | | 0 | 7.41 | 5.015 |
| OAT FR0000186199 | 25.10.1999 | 20,821 | 4 | 25.10.2009 | 1.041025 | 1,122 (5.39% of outst. amount) | | 65 | 7.81 | 5.12 |
| Bund 113513 | 22.10.1999 | 11,000 | 5.375 | 04.01.2010 | 1.156354 | | | 0 | 7.62 | 5.015 |
| Total deliv. volume | | 138,085 | | | | | | | | |

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

**Correlations (daily/weekly)**

| | Germany | | France | | Italy |
|---|---|---|---|---|---|
| | Benchmark bond | CTD bond | Benchmark bond | CTD bond | Benchmark bond |
| | 113513 | 113507 | 186199 | 186199 | |
| Euro Bund future | 0.939/0.985 | 0.938/0.979 | 0.931/0.978 | 0.931/0.978 | 0.835/0.965 |
| Euro Notional future | 0.965/0.982 | 0.971/0.978 | 0.973/0.987 | 0.973/0.987 | 0.930/0.972 |
| Euro swaps | 0.933/0.966 | 0.938/0.958 | 0.932/0.951 | 0.932/0.951 | 0.848/0.937 |

Daily period: 20.10.99-13.12.99. Weekly period: 29.10.99-10.12.99. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.7

## 10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): March 2000 delivery

**10Y Euro Bund futures contract March 2000 (09.12.99-08.03.00; delivery: 10.03.00)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 0.849146 | 107.6 (0.77% of outst. amount) | 703,749 (03.02.00) | 2 | 7.13 | 5.443 |
| 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 0.859902 | 5 (0.45% of outst. amount) | | 0 | 7.16 | 5.445 |
| 113512 | 09.07.1999 | 20,000 | 4.500 | 04.07.2009 | 0.894982 | 1,366 (6.83% of outst. amount) | | 59 | 7.11 | 5.46 |
| 113513 | 22.10.1999 | 20,000 | 5.375 | 04.01.2010 | 0.953876 | | | 0 | 7.32 | 5.449 |
| Total deliv. volume | | 65,000 | | | | | | | | |

**10Y Euro Notional futures contract March 2000 (14.12.99-13.03.00; delivery: 17.03.00)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| OAT FR0000570665 | 25.10.1997 | 16,799 | 8.5 | 25.10.2008 | 1.366054 | | 155,639 (14.02.00) | 0 | 6.17 | 5.298 |
| Bund 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 1.018574 | | | 0 | 7.14 | 5.313 |
| OAT FR0000571432 | 25.04.1998 | 22,522 | 4.000 | 25.04.2009 | 1.038381 | | | 0 | 7.06 | 5.395 |
| Bund 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 1.038875 | | | 0 | 7.17 | 5.319 |
| Bund 113512 | 09.07.1999 | 20,000 | 4.500 | 04.07.2009 | 1.078107 | | | 0 | 7.12 | 5.331 |
| OAT FR0000186199 | 25.10.1999 | 23,874 | 4 | 25.10.2009 | 1.040069 | 1,125.4 (4.71% of outst. amount) | | 64 | 7.53 | 5.421 |
| Bund 113513 | 22.10.1999 | 11,000 | 5.375 | 04.01.2010 | 1.152988 | | | 0 | 7.34 | 5.321 |
| Total deliv. volume | | 119,195 | | | | | | | | |

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

**Correlations (daily/weekly)**

| | Germany | | France | | Italy |
|---|---|---|---|---|---|
| | Benchmark bond | CTD bond | Benchmark bond | CTD bond | Benchmark bond |
| | 113513 | 113512 | 186199 | 186199 | |
| Euro Bund future | 0.839/0.895 | 0.897/0.906 | 0.903/0.928 | 0.903/0.928 | 0.807/0.804 |
| Euro Notional future | 0.877/0.962 | 0.961/0.966 | 0.956/0.960 | 0.956/0.960 | 0.898/0.899 |
| Euro swaps | 0.824/0.824 | 0.890/0.843 | 0.897/0.884 | 0.897/0.884 | 0.768/0.683 |

Daily period: 10.12.99-13.03.00. Weekly period: 17.12.99-10.03.00. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.8

## 10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): June 2000 delivery

**10Y Euro Bund futures contract June 2000 (09.03.00-08.06.00; delivery: 12.06.00)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 0.852420 | 4,329.2 (30.9% of outst.amount) | 842,199 (19.05.00) | 36 | 6.92 | 5.233 |
| 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 0.863172 | | | 0 | 6.95 | 5.221 |
| 113512 | 09.07.1999 | 20,000 | 4.500 | 04.07.2009 | 0.897383 | | | 25 | 6.9 | 5.222 |
| 113513 | 22.10.1999 | 20,000 | 5.375 | 04.01.2010 | 0.954764 | | | 0 | 7.12 | 5.196 |
| 113515 | 05.05.2000 | 8,000 | 5.250 | 04.07.2010 | 0.944136 | | | 0 | 7.64 | 5.178 |
| Total deliv. volume | | 73,000 | | | | | | | | |

**10Y Euro Notional futures contract June 2000 (14.03.00-19.06.00; delivery: 23.06.00)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| Bund 113510 | 08.01.1999 | 14,000 | 3.750 | 04.01.2009 | 1.018025 | | 159,373 (23.03.00) | 0 | 6.91 | 5.145 |
| OAT FR0000571432 | 25.04.1998 | 22,522 | 4.000 | 25.04.2009 | 1.037395 | 0.2 (0.0009% of outst. amount) | 637,010 (06.06.00) | 0 | 7.13 | 5.276 |
| Bund 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 1.038136 | | | 0 | 6.94 | 5.128 |
| Bund 113512 | 09.07.1999 | 20,000 | 4.500 | 04.07.2009 | 1.076324 | | | 0 | 6.9 | 5.127 |
| OAT FR0000186199 | 25.10.1999 | 23,874 | 4 | 25.10.2009 | 1.039126 | 867.5 (3.63% of outst. amount) | | 8 | 7.3 | 5.272 |
| Bund 113513 | 22.10.1999 | 11,000 | 5.375 | 04.01.2010 | 1.149461 | | | 0 | 7.11 | 5.121 |
| OAT FR0000186603 | 25.04.1999 | 13,201 | 5.5 | 25.04.2010 | 1.164066 | 0.1 (0.0008% of outst. amount) | | 58 | 7.42 | 5.271 |
| Bund 113515 | 05.05.2000 | 8,000 | 5.250 | 04.07.2010 | 1.145740 | | | 1 | 7.63 | 5.104 |
| Total deliv. volume | | 123,597 | | | | | | | | |

Calculation of open interest changed by MATIF on 23.05.00 from net open interest to gross open interest; EUREX calculates net open interest.
Example: There are two clients for one member: First client: 10 long, 20 short, Second client: 50 long, 30 short, Sum: 60 long, 50 short; Net open interest: 10 long=10; Gross open interest: 10 short and 20 long=30.

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

**Correlations (daily/weekly)**

| | Germany | | France | | Italy |
|---|---|---|---|---|---|
| | Benchmark bond | CTD bond | Benchmark bond | CTD bond | Benchmark bond |
| | 113515 | 113510 | 186603 | 186603 | |
| Euro Bund future | 0.946/0.999 | 0.956/0.995 | 0.926/0.995 | 0.926/0.995 | 0.908/0.952 |
| Euro Notional future | 0.971/0.995 | 0.976/0.997 | 0.970/0.999 | 0.970/0.999 | 0.959/0.968 |
| Euro swaps | 0.925/0.908 | 0.928/0.939 | 0.935/0.936 | 0.935/0.936 | 0.940/0.990 |

Daily period: 03.05.00-19.06.00. Weekly period: 12.05.00-16.06.00. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.9

## 10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): September 2000 delivery

**10Y Euro Bund futures contract** September **2000 (09.06.00-07.09.00; delivery: 11.09.00)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 0.865974 | | 614,649 (10.08.00) | 1 | 7.09 | 5.306 |
| 113512 | 09.07.1999 | 20,000 | 4.500 | 04.07.2009 | 0.899414 | 2,127.7 (10.63% of outst. amount) | | 61 | 6.99 | 5.305 |
| 113513 | 22.10.1999 | 20,000 | 5.375 | 04.01.2010 | 0.955835 | | | 1 | 6.88 | 5.267 |
| 113515 | 05.05.2000 | 18,000 | 5.250 | 04.07.2010 | 0.944942 | | | 0 | 7.39 | 5.264 |
| Total deliv. volume | | 69,000 | | | | | | | | |

**10Y Euro Notional futures contract September 2000 (20.06.00-18.09.00; delivery: 22.09.00)**

| Deliverable bonds | Start of accrued interest | Outstanding amount (Million Euro) | Coupon | Maturity | Conv. factor | Deliverable volume (Million Euro) | Open interest (high) | Days being CTD | Mod. duration | Yield |
|---|---|---|---|---|---|---|---|---|---|---|
| OAT FR0000571432 | 25.04.1998 | 22,522 | 4.000 | 25.04.2009 | 1.036411 | | 644,715 (28.07.00) | 0 | 6.87 | 5.474 |
| Bund 113511 | 26.03.1999 | 11,000 | 4.000 | 04.07.2009 | 1.037161 | | | 0 | 7.06 | 5.372 |
| Bund 113512 | 09.07.1999 | 20,000 | 4.500 | 04.07.2009 | 1.074422 | | | 0 | 6.95 | 5.369 |
| OAT FR0000186199 | 25.10.1999 | 23,874 | 4.000 | 25.10.2009 | 1.038331 | 112.3 (0.47% of outst. amount) | | 19 | 7.03 | 5.495 |
| Bund 113513 | 22.10.1999 | 20,000 | 5.375 | 04.01.2010 | 1.146277 | | | 0 | 6.84 | 5.341 |
| OAT FR0000186603 | 25.04.1999 | 17,692 | 5.500 | 25.04.2010 | 1.160453 | 630.3 (3.56% of outst. amount) | | 46 | 7.15 | 5.495 |
| Bund 113515 | 05.05.2000 | 18,000 | 5.250 | 04.07.2010 | 1.142579 | | | 0 | 7.35 | 5.344 |
| Total deliv. volume | | 133,088 | | | | | | | | |

Open interest is calculated by MATIF as gross open interest, by EUREX as net open interest.

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

**Correlations (daily/weekly)**

| | **Germany** | | **France** | | **Italy** |
|---|---|---|---|---|---|
| | Benchmark bond | CTD bond | Benchmark bond | CTD bond | Benchmark bond |
| | 113515 | 113512 | 186603 | 186603 | |
| Euro Bund future | 0.888/0.931 | 0.888/0.941 | 0.894/0.95 | 0.894/0.95 | 0.894/0.943 |
| Euro Notional future | 0.943/0.975 | 0.942/0.981 | 0.956/0.998 | 0.956/0.998 | 0.946/0.975 |
| Euro swaps | 0.780/0.919 | 0.781/0.919 | 0.783/0.95 | 0.783/0.95 | 0.797/0.934 |

Daily period: 12.06.00-18.09.00. Weekly period: 16.06.00-15.09.00. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

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